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DISTRIBUTION PATTERN OF BUTTERFLIES (LEPIDOPTERA: RHOPALOCERA) IN DIFFERENT HABITATS OF DISTRICT HARIDWAR, UTTARAKHAND

A

THESIS

Submitted for the Award of Degree

of

DOCTOR OF PHILOSOPHY

IN

ZOOLOGY

Supervisor

Prof. NAMITA JOSHI
Professor
Department of EnvironmentalSciences
(GKV), Kanya Gurukul Campus, Haridwar

Submitted By

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CHAPTER - 1

INTRODUCTION

"Biodiversity" is the key to the maintenance of the world. The value of it makes our ecosystems more resilient, which is prerequisite for stable societies."

John Rock Strom

The biosphere includes a broad variety of organisms and habitats. The term "biodiversity," which can alternatively be written as "biological diversity," refers to the wide range of organisms found in ecosystems (IUCN et al., 1990; Convention on Biological Diversity, 1992). Biodiversity is important for human sustenance because of its role in maintaining healthy ecosystems (Duffy, 2009; Gascon et al., 2015; Lohbeck et al., 2016).

Everywhere on Earth has life, including the poles and the equator, the ocean floor and several miles in the air, frigid oceans and desert valleys, undersea thermal vents, and groundwater hundreds of feet below the planet's surface. However, ongoing losses in biodiversity and ecosystem services threaten the foundations of economies, water and food security, livelihoods, health, and quality of life (Diaz et al., 2006; Brondizio et al., 2019). Biodiversity has led to the evolution and adaptation of life on Earth to virtually every imaginable setting. Despite the incredible diversity of life, there are some features shared by all organisms. The dispersal of species is influenced by factors such as climate and topography. Ecosystem stability is the consequence of interactions between groups of interdependent species that coordinate in various ways. There is a wide variety of life forms present at every level. Ecosystems, species, populations, and even single people can all contain such variety.

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the thesis entitled **"DISTRIBUTION PATTERN OF BUTTERFLIES (LEPIDOPTERA: RHOPALOCERA) IN DIFFERENT HABITATS OF DISTRICT HARIDWAR, UTTARAKHAND"** in fulfilment of the requirements for the award of the Degree of Doctor of Philosophy in **Zoology** of Gurukula Kangri (Deemed to be University), Haridwar, is an original work carried out by me during a period from April 2019 to April 2023 under the supervision of **Prof. Namita Joshi, Department of Environmental Sciences, Gurukula Kangri (Deemed to be University), Haridwar**

The matter presented in the thesis has not been submitted by me for the award of any other degree of this Deemed to be university or any other University/Institute. I have properly acknowledged the material collected from the secondary sources wherever required. I solely own the responsibility for the originality of the entire content.

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Date: 29-09-2023

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Shivalika Sharma

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The candidate has fulfilled the necessary residency requirements for full time Ph.D. Programme as per rules of the University.

I recommend the thesis for evaluation for the award of the Degree of Doctor of Philosophy of Gurukula Kangri (Deemed to be University), Haridwar.

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Place: Haridwar

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The Ph.D. thesis submitted by **Mrs. Shivalika Sharma** in the subject of **Zoology** under the supervision of **Prof. Namita Joshi,** Department of Zoology and Environment Science, Gurukula Kangri (Deemed to be University), Haridwar is hereby forwarded for evaluation for the award of the Degree of **Doctor of Philosophy** of **Gurukula Kangri (Deemed to be University) Haridwar, India.**

It is also certified that the candidate has made the **pre-submission presentation** before DRC on **20th April 2023** and the necessary residency requirement as per the rules of the Vishwavidyalaya/University.

29/9/23

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Shivalika Sharma,

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Dedicated to...

My Father and Brother

This thesis is dedicated to the memory of my father (Bishan Dass Sharma) and brother (Sushant sharma). I miss him every day , but I am glad to know he saw this process through to its completion. Offering the support to make it possible, as well as plenty of friendly encouragement.

My Mother

A strong and gentle soul who has been my greatest supporter of my education. She encouraged me to do it and she believed I could do great.

My Husband

Thanks for your constant source of support and encouragement during the challenges of Ph.D. and in my life. I am truly thankful for having you in my life.

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ABBREVIATIONS

S. No.	Acronyms	Full forms
1	Gm.	Gram
2	Cm.	Centimetre
3	M.	Meter
4	Km.	Kilometre
5	IUCN	International Union for Conservation of Nature
6	^{0}C	Centigrade
7	IPBES	Intergovernmental Platform on Biodiversity and Ecosystem service
8	%	Per cent
9	UN	United Nations
10	ha	Hectare
11	CBD	Conventional on Biological diversity
12	IFTA	Insect farming and trade agency
13	Sq km	Square kilometer
14	FSI	Forest survey of India
15	Etc	Et cetera
16	IHR	Indian Himalayan Region
17	WPSI	Wildlife Protection Society of India
18	mm	Millimetres
19	et al.	Others
20	e.g.	For Example
21	viz.	That is to say
22	Ed.	Edition
23	https.	Hyper Text Transfer Protocol secure
24	WWW	World Wide Web
25	Org.	Organization
26	ZSI	Zoological Survey of India
27	IARI	Indian agricultural Research Institute
28	FRI	Forest Research Institute
29	Rh	Relative humidity
31	UCOST	Uttarakhand State Council for Science & Technology

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CHAPTER - 1

INTRODUCTION

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CHAPTER - 1

INTRODUCTION

"Biodiversity" is the key to the maintenance of the world. The value of it makes our ecosystems more resilient, which is prerequisite for stable societies."

John Rock Strom

The biosphere includes a broad variety of organisms and habitats. The term "biodiversity," which can alternatively be written as "biological diversity," refers to the wide range of organisms found in ecosystems (IUCN *et al.*, 1990; Convention on Biological Diversity, 1992). Biodiversity is important for human sustenance because of it's role in maintaining healthy ecosystems (Duffy, 2009; Gascon *et al.,* 2015; Lohbeck *et al.*, 2016).

Everywhere on Earth has life, including the poles and the equator, the ocean floor and several miles in the air, frigid oceans and desert valleys, undersea thermal vents, and groundwater hundreds of feet below the planet's surface. However, on going losses in biodiversity and ecosystem services threaten the foundations of economies, water and food security, livelihoods, health, and quality of life (Diaz *et al.*, 2006; Brondizio *et al.*, 2019). Biodiversity has led to the evolution and adaptation of life on Earth to virtually every imaginable setting. Despite the incredible diversity of life, there are some features shared by all organisms. The dispersal of species is influenced by factors such as climate and topography. Ecosystem stability is the consequence of interactions between groups of interdependent species that coordinate in various ways. There is a wide variety of life forms present at every level. Ecosystems, species, populations, and even single people can all contain such variety.

Hosetti, (2002) defines biodiversity as the sum of all the known genes, species, and ecosystems on Earth. It includes every kind of living things from bacteria to trees to animals in the entire biosphere. In a complex ecosystem, different species are responsible for different things, such as recycling nutrients and providing food, water, and energy. The loss of even a single species in such complex ecosystems can have

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far-reaching consequences. India has a very high biodiversity and is considered one of the world's 12 mega-diverse countries. The term "biodiversity" is often used interchangeably with "variety of life," in the scientific, academic, and policy communities. Both between and within regions, biodiversity is very variable. It was discovered whether or not areas with a high concentration of species were likely to host a considerable number of unusual species by analysing insect diversity hotspots of different groups (Prendergast *et al.,* 1993). According to the IUCN's (2020) evaluation of only a small fraction of the world's described species, only 5% of the (1,28,918 species) 35,765 are threatened with extinction. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services estimates that half a million species could become extinct in the next few decades, and that most of these are insects (Watson *et al.*, 2019), which contributes maximum number of species diversity among the faunistic biodiversity of ecosystem. Thus, the UN Convention on Biological Diversity (CBD, 2012) stressed the importance of protecting biodiversity and mandated that all signatory countries, including India, compile and publish an inventory of their biological variety. The UN has designated the years 2021-2030 as the UN Decade on Ecosystem Restoration. The aim of this programme is to maintain ecosystems and biodiversity in the face of climate change by protecting and restoring a wide range of landscapes and habitat types (Temperton *et al.*, 2019).

One of the most well-known biodiversity hotspots, the Indian Himalayan Region (IHR) is home to a great range of indigenous plants and animals due to its unique geological composition and recent history of formation (Myers *et al.*, 2000; Marchese, 2015). The IHR covers over 17% of India's total land area, or 5.3 million square kilometres. The monsoons deliver heavy and plentiful precipitation to this region, which is home to the world's highest and youngest parallel series of mountains (Singh and Singh, 1987). As the "Third Pole" of the Earth, the Himalayas are home to a large number of glaciers (Kulkarni and Karyakarte, 2014). Different types of forests, a wide variety of cultural and biological diversity, and a wide variety of topography and environmental conditions along significant elevational gradients are all gifts bestowed upon the IHR (Singh, 2006a; Ramakrishnan, 2007). It is estimated that the Himalayas are home to 150 animal species and 4,713 plant species (Singh and Kushwaha, 2008; Pandit and Kumar, 2013). However, the Himalaya has one of the worst rates of deforestation in the world due to human pressures such as urbanisation, hydropower

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development, agricultural expansion and intensification, excessive logging, grazing, and others.

The state of Uttarakhand is distinctive for its abundant biodiversity, with a total area of 53,483 sq. km, of which 65% area under forest. This area has become habitat for a lot of insect communities. Researchers have catalogued and studied close to a million unique insect species all over the globe. Numerous insects populate numerous ecosystems. They are important indications for places with lots of species, so they need to be protected both as topics of conservation and as a way to find places with plenty of endemism. Humans can be affected by both helpful and harmful insects. Roughly 10% of bug species have unresolved mysteries surrounding their identification. It is believed that many species become extinct without ever being given a name. Cutting down and burning tropical rainforests at the current rate could lead to the extinction of at least one-fourth of all species on Earth (Wilson, 1999). We cannot fathom a world without insects. The ecological food chain, food webs, biomass, and species richness are all reliant on the presence of insects. Most insects, for instance, get the vast majority of their nutrition from plant matter, making them key consumers and a source of protein for animals that eat them. Some of them prey on plants, while others attack animals. Class Hexapoda (Greek: hexa = six, poda = legs) is the most common and important insect category within the phylum Arthropoda (Greek: arthro = segmented or connected, poda = legs; Samways, 2005). There are an estimated 6.1 million insect species (Stork, 2018; Zhang, 2011), making them the most hyper-diverse and fascinating group of animals. The Order Lepidoptera (Gk. lepis = scale, pteron = wing) is the second largest and most well-known insect order (Kristensen *et al.*, 2007; Stork, 2018), with a total of 1, 57, 338 named and described species worldwide. In forest ecosystems, the order is an integral part of the "green" food webs (Kitching *et al.*, 2020). Moths with different antennae (including butterfly species with club-shaped antennae) are further divided into the suborders Heterocera and Rhopalocera. Numerous butterfly families, including the Hesperiidae, Papilionidae, Pieridae, Nymphalidae, Lycaenidae, and Riodinidae, belong to the Rhopalocera's monophyletic superfamily Papilionoidea (Heikkila *et al.*, 2012).

Over 19,000 known butterfly species belong to these families (van Nieukerken *et al.*, 2011), including 18,732 named and valid species found in every region of the globe.

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INTRODUCTION

Recent family-level phylogenomic analyses show that butterflies formed around 119 Mega annum (Ma) during the late Cretaceous period and diverged around 65 Ma later during the Cretaceous-Paleogene epoch (Espeland *et al.*, 2018). As of 2018, 1,013 butterfly species had been documented in the IHR, 508 in the state of Uttarakhand and 1,501 across the Indian subcontinent (Das *et al.*, 2018; Kehimkar, 2016; Sondhi and Kunte, 2018).

Butterflies are easily recognisable due to their day time activity and extensive taxonomic study. The ecological and global distribution information for class Insecta is extensive. Butterflies serve as an excellent example of how biotic and abiotic factors can interact in intricate ways with one another (Pollard, 1988). Grasslands, scrublands, gardens, fields, deserts, and woods are only some of the places you might find them, but they can also be discovered in the tropics, the circumpolar snow regions, coastal areas, and even the highest mountains (Mani, 1986). Butterflies are some of the most charming and fragile creatures due to their colourful wings, which varies in range, brilliance, and pattern. Butterflies are often referred to as the "Winged Jewels of Creation" because of the variety of ways in which they can appear (New *et al.*, 1995; Fleishman and Murphy, 2009; New, 2011).

Several well-known butterfly species are being used as flagship taxa in conservation programmes. Even more seriously, butterflies are negatively affected by the loss of habitat and ongoing changes to the landscape (Dirzo *et al.*, 2014). They have major repercussions for the Rapid Biodiversity Assessment (RBA) project developed by Conservation International to track ecosystems and endangered regions. The RBA method, which uses the butterfly as a target taxon, yields high-quality data at little cost that can be used to better understand environmental phenomena and to better manage biodiversity protection (Hayes *et al.*, 2009; Bhardwaj *et al.*, 2012). Butterflies are significant from many different perspectives, including ecological, scientific, economic, aesthetic, and recreational. Butterflies play an important role in terrestrial ecosystems and provide both direct and indirect benefits to humans, making them more than merely biological markers (Gilbert and Singer, 1975; Bonebrake *et al.*, 2010).

Climatic parameters like, rainfall, temperature, humidity influence distribution and composition of species. Rainfall functions as a regulator of butterfly diversity and

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abundance. Temperature and humidity fluctuations have been shown to have a significant impact on butterfly populations (Brown and Freitas, 2000; Ojianwuna, 2015; Kumar *et al.*, 2017). Changes in precipitation due to the El Nino-Southern Oscillation (ENSO) phenomenon affect butterfly population dynamics, migration patterns, and host plant phenology (Srygley *et al.*, 2010; Pardikes *et al.*, 2015; Beaumont *et al.*, 2017). Wang *et al.*, (2016) found that the abundance of temperate and tropical butterfly species had declined by 50% and 88%, respectively, as a result of strong cold episodes brought on by global climate change. Researchers have found that climate change poses a greater threat to the survival of butterflies native to temperate or montane regions (Karlsson, 2014; MacLean *et al.*, 2016). The frequency, intensity, and seasonality of rainfall changes are all on the rise (Menzel *et al.*, 2006). It is commonly believed that rain is beneficial for butterfly larvae because it helps the plants that the larvae feed on develop (Pollard, 1988; Roy *et al.*, 2001).

Davies *et al.*, (2005) found that temperature has direct or indirect effects on oviposition site choice, egg laying rates, larval growth and survival rates, and range shifts and expansions. Rodriguez *et al.*, (1994), reported that host plant's phenology being altered by precipitation, and it has an effect on larval development and survival. Individual host plants are the primary food supply for prediapause larvae because inter-plant distances frequently exceed larval dispersal ranges (Weiss *et al.*, 1993). Larvae are unable to travel far from their natal plant to locate a new host if it has become defoliated or senescent (Hayes, 1985). If the host plant dies before the larvae reach diapause, they will starve to death unless they can find another plant to use as a food source. Sexual reproduction in many plants is aided by insect pollination (Faegri and Van der, 1979; Proctor *et al.*, 1996). This accounts for about 39% of the total economic value of agricultural output and includes the production of 75% of all food crops farmed worldwide (Gallai *et al.*, 2009). Butterflies play a crucial role in the crop production and reproductive success of a variety of blooming plants in natural habitats (Courtney *et al.*, 1982; Kunte, 2000; Borges *et al.*, 2003; Rader *et al.*, 2016.) Adult butterflies, in particular, visit many different kinds of flowers during the day for nectar, and they pick up pollen grains from many of these visits and carry them on their wings, heads, legs, thorax, and proboscis. Plants can become xenogamous and acquire genetic variations because the adhering pollen frequently falls on the

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stigmatic surface of another conspecific flower (Reddi and Bai, 1984). Butterflies play a crucial role in long-distance pollination due to their ability to travel greater distances over time, resulting in greater flower coverage over a larger area.

Butterflies and plants have developed a mutualistic, symbiotic relationship over time, and the variety of flowering plants used by butterflies as nectar has evolved to mirror, or counteract, the variety of butterfly species (Lebeau *et al.*, 2016; Lebeau *et al.*, 2018). After millions of years of coevolution, many flowering plants now exhibit psychophilous mode of pollination, most commonly to attract pollinators (Proctor *et al.*, 1996; Cruden and Hermann-Parker, 1979; Balducci *et al.*, 2019).

Butterflies migrate when adult populations move seasonally away from unfavourable environmental conditions in a certain direction. Short and medium distance migration is typically distinguished from long-distance migration (Gupta, 1991; Bhaumik and Kunte, 2020). Many butterfly species have vast populations that regularly engage in long-distance migrations for reasons that include evading rain, cold, crowding, and lack of food and shelter. *Vanessa cardui* is the most well-known migratory butterfly, migrate from Europe to subtropical Africa, with individuals traveling up to 4,000 kilometers (Kehimkar, 2016). More than 64 species of migrating butterflies have been spotted in India (Palot, 2012). Butterflies are known to make a seasonal migration through the Himalaya in order to escape the colder temperatures and heavier precipitation seen at higher altitudes (Mani, 1986). The *Pieris brassicae* (Pieridae) butterfly, for instance, migrates from higher elevations to lower ones in the early winter and back again in the summer (Jamdar, 1991). Similar to how many butterflies in the Western Ghats of peninsular India fly southward when the monsoons arrive several species of these insects move from the northeast to the southwest during this time (Larsen, 1978; Mathew and Binoy, 2002; Palot *et al.*, 2002; Kunte, 2005). Butterflies are representative of a rich tapestry of species interactions in ecological food webs. For butterfly populations to thrive, host variety and species richness must increase, and the larvae of these insects, which are phytophagous, play a key role as the primary consumers in this process (Stork, 2007; Ferrer-Paris *et al.*, 2013). Furthermore, predatory creatures at higher trophic levels rely on the larval stages as a key source of food, and this includes birds, reptiles, amphibians, squirrels, mice, scorpions, spiders, wasps, ants, and beetles, among others (Janzen, 1988). Each

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butterfly species has its own community of parasitoids, or insect parasites, which may or may not be species-specific (Smith *et al.*, 2008). Larvae and pupae are preyed upon by parasitoids such as tachinoid flies, chalcid wasps, ichneumonid wasps, and braconid wasps (Ehrlich, 1984; Obregón *et al.*, 2015). That's why butterflies are so important to terrestrial ecosystems; in their larval stages, they facilitate the flow of energy from primary producers to secondary consumers, and in their adult stages, they take part in pollination, an ecological process that ensures plant life and helps restore depleted areas. During the larval stage, they contribute to the nutrient cycle by excreting their waste, which often contains nitrogen, phosphorus, and potassium (Marchiori and Romanowski, 2006). Mutualistic and parasitic relationships with ants are common among Lycaenidae butterflies (Pierce *et al.*, 2002; Fiedler, 2006). The presence of many different species and a high population density of butterflies is indicative of a healthy ecosystem and a secure setting (Kremen, 1992, 1994; Andrew *et al.*, 2011).

Butterflies are regarded as powerful indicators of ecological conditions including environmental and land use changes, habitat quality and degradation, productivity regimes and forest cover, and toxicity levels (Brown and Freitas, 2000; Hayes *et al.*, 2009; Erhardt, 1985; Brown, 1997; Lawton *et al.*, 1998; Balmer and Erhardt, 2000; Nordqvist, 2009; Legal *et al.*, 2020). Butterflies can also serve as valuable model species for predicting the consequences of climate change. Butterflies have immense scientific importance in fields as diverse as biomechanics, physiology, developmental biology, ecology, behaviour, evolution, speciation, systematics, genetics, global warming, and biodiversity protection. Insect-sized flying microrobots can be designed inspired by the flight and wing shapes of butterflies (Warren *et al.*, 2001; Davies, 2019; Ancel *et al.*, 2017). Literature have shown that butterfly species extracts can kill bacteria or act as an antibiotic, antihaemorrhagic, and kill cancer cells (Garcia, 1948; Rasooly *et al.*, 2017; Komatsu *et al.*, 2001; Shen *et al.*, 2016). Out of the 400 species of Lepidoptera, 47 are used for human consumption or medical purposes (Yen, 2015). Farming and ranching (captive breeding) present opportunities for conservation and worldwide trade because of the high demand for many endangered butterflies (Collins and Morris, 1985; Parsons, 1992; New, 1994). In New Guinea, for instance, the IFTA (Insect Farming and Trade Agency) earns about $400,000 annually from the sale of

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insects like ranched butterflies (Orsak, 1993). Local economies gain from the trading of butterflies for souvenirs including key chains, envelopes, frames, bracelets, and necklaces (Putri, 2016). The larvae of just about 15 butterfly species are considered major crop pests worldwide, and this number is even smaller in the Indian subcontinent (Varshney, 1978). Many insect species and populations are declining and in danger of extinction as a result of anthropogenic drivers of global change, giving rise to the new phenomenon known as the "Insect Apocalypse" and necessitating primary and immediate conservation goals (Fox *et al.*, 2019; Didham *et al.*, 2020; Wagner, 2020; Forister *et al.*, 2019; Montgomery *et al.*, 2020). At the current rate of decline, some 40 percent of insect species in the world could go extinct in the next several decades (Sánchez-Bayo and Wyckhuys, 2019). Butterflies are among the most sensitive species to even small shifts in climate and habitat in terrestrial ecosystems and they are also among the quickest to adapt to new conditions (Erhardt and Thomas, 1991; Thomas *et al.*, 2004). It is estimated that seven percent of all species in India are in danger of extinction due to human activity (Raju and Rao, 2002). Loss of habitat, invasive alien species, climate change, pollution, toxins, and commercial exploitation are the greatest threats to butterflies.

There are two main categories of butterfly life in the Himalayas: woodland species and hysobiont species. Only on the outer Himalayan range's steep, forested slopes can you find these forest species. True high-altitude forms, the hysobiont species, are only ever found above the tree line. The Indian Himalayan Region has been the subject of numerous studies on butterfly diversity and ecology (Chandel *et al.*, 2013; Joshi and Singh, 2013; Singh and Banyal, 2014; Kumar *et al.*, 2016). The Indian Himalayan Region is a repository for rich biological diversity and to ensure its proper conservation, protected areas in the form of Biosphere Reserves, National Parks, Sanctuaries and Conservation Reserves have been established (Rodgers and Panwar, 1988). With a total area of 53,485 sq km and the newest Himalayan state in India, Uttarakhand, there are abundant natural resources and a great variety of species. Almost 64.79% of the entire geographic area is categorized as forest, however only 35% of that area is covered by forests (FSI, 2011). The state has experienced numerous man-made disasters that have exacerbated natural disasters in recent years, having a significant negative impact on the local ecology (Tayal *et al.*, 2019). Butterflies prefer a particular set of habitats and host plants for their survival. Being

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sensitive to the temperature, humidity and light levels and also to disturbances and changes in the quality of habitat they are regarded as potential indicator species of environmental quality and healthy ecosystems (Gunathilagaraj *et al.*, 1998; Balmer and Erhardt, 2000; Thomas, 2005). There are about 1,504 species of butterfly fauna in the Indian subcontinent and 323 species of butterfly fauna have been recorded from the state of Uttarakhand (Tiple, 2011; Kumar, 2008). Uttarakhand hosts a range of diverse floral and faunal richness. Geographically, it shares the part of both Central and Western Himalayan region and is located in the central sector of Himalaya, thus owing to its vivid and rich biodiversity. According to Joshi and Arya, (2007) there are about 54 species and 9 families recorded from Nanda Devi Biosphere in Uttarakhand out of which the family Nymphalidae was the most abundant both in terms of number of species and individuals. Several research on the diversity of butterflies have been carried out in this state, although they are either limited to protected regions alone and in few specific habitats (Arora, 1997; Bhardwaj *et al.*, 2012; Arya and Dayakrishna, 2017; Kumar *et al.*, 2017; Smetacek, 2012; Arya *et al.*, 2016).

However, after going through the literature it shows that no such studies have been conducted in District Haridwar, particularly on diversity, species composition and distribution pattern of butterflies in various habitats. Studies on butterflies and floral interactions have also not been carried out in and around this area. Thus, this study has been designed to investigate with following objectives:

- Determination of floral resources available for butterflies in different study sites.
- Species composition and population dynamics of butterflies in different study sites.
- Comparison of species diversity of butterflies of different study sites.
- Role of ecological variables *viz.* temperature, humidity, soil type and anthropogenic disturbances on the abundance of butterflies.

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CHAPTER - 2

REVIEW OF LITERATURE

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CHAPTER - 2

REVIEW OF LITERATURE

In ancient Greece, the philosopher Aristotle, way back in the Classical Period (384–322 BC), provided us with the earliest written account of Lepidoptera, the group of insects that includes butterflies. Over the centuries, numerous researchers have added to our knowledge of these winged creatures. Some notable contributors include Gaius Plinius, Albertus Magnus, Ulysses Aldromandus, Thomas Mouffet, Edward Topsell, Marcello Malphigi, Jean Goedart, Jan Swammerdam, Rene Reaumur, Martin Lister, James Petiver, John Ray, Christopher Merrett, Benjamin Wilkes, Charles De Geer, and Moses Harris (Smart, 1975).

The real scientific groundwork for the classification and naming of butterflies started with the Swedish naturalist Carl Linnaeus in 1758 when he published "Systema Naturae." Linnaeus described many butterfly species, including several from Europe, laying the foundation for modern taxonomy.

Since then, extensive research on butterflies from all around the world has expanded our understanding. Notable contributions include works by Eliot, (1969); Higgins and Riley, (1970); Owen, (1971); Vane-Wright, (1975); D'Abrera, (1982, 1985, 1986); Ackery, (1984); Heppner, (1991, 1998); Hassan, (1994, 1997); Smith, (1994); Borner, (1925); Thomas-Glover, (1936); Hennig, (1953); Ehrlich, (1958); Munroe and Ehrlich, (1960); Munroe, (1961) and many more.

In the Indian context, research on butterflies has also made significant strides. Shamsudeen and Mathew, (2010) documented 73 butterfly species in the Shenduruny Wildlife Sanctuary in Kerala, including some unique to the Western Ghats and species protected by Indian wildlife laws. Tiple, (2012) discussed the diversity of butterflies in the Jabalpur Tropical Forest Research Institute, discovering 66 species from five families. Manzoor and Bin Sadat., (2013) explored the ecological role of butterflies as bioindicators, and Sengupta *et al.*, (2014) studied the butterfly diversity near the Neora Valley National Park, recording 143 host plants for various butterfly species.

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Kumar, (2015) found 37 genera and 7 families of butterflies along the Sirhind Canal Mainline in Punjab, India. Nandakumar *et al.,* (2015) studied butterfly diversity in the Manikkunnumala forest in the Indian Western Ghats, identifying 94 species from 66 genera. Harsh *et al.,* (2015) examined butterflies in the Kanha-Pench corridor in central India, discovering 59 species from six families, with Nymphalidae being the most abundant. Lodh and Agarwala, (2016) used the Rapid Biodiversity Assessment approach to identify 53 butterfly species in Tripura, Northeast India.

Abusarhan *et al.,* (2016) described 54 butterfly species from the occupied Palestinian Territory. Mal *et al.,* (2016) provided detailed information about the genus *Junonia* and identified two new species from Pakistan. Patil *et al.*, (2017) discovered 84 butterfly species from 54 genera and 5 families.

Narayana *et al.*, (2017) focused on 20 distinct butterfly species in Warangal's woodlands during winter. Singh and Ahmad, (2017) detected 89 moth species in Palkot Natural Life Safe-Haven, Jharkhand. Khyade and Jagtap, (2017) found 13 species in the Mayureshwar Wildlife Sanctuary.

Chettri *et al.*, (2018) identified 44 distinct butterfly species in Southern Sikkim, Eastern Himalaya. Gupta and Mondal published the Red Data book for Indian Butterflies in 2005. Varshney, (2006) examined 1,500 butterfly species from the Indian subcontinent, and Smetacek, (2007) introduced a Captain Butterfly agenda for South Asia. Kehimkar, (2008) published a book covering 735 distinct butterfly species in India, and Varshney, (2008–2009) released the Primary Catalog of Indian Locale Butterflies. In 2015, Varshney and Smetacek, (2015) listed 1,318 butterfly species in India. According to Kehimkar, (2016), there are 1,501 species of butterflies in India. Smetacek, (2016) published a naturalist's guide to the butterflies of the Indian subcontinent. Singh, (2017b) contributed to the knowledge of Indian butterflies.

In India, several institutions and groups, including the Bombay Natural History Society, the Wildlife Institute of India, the Indian Agricultural Research Institute, and the Zoological Survey of India, have been actively involved in butterfly research. Unfortunately, despite these efforts, there is still much more to learn about butterflies

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in India, including their distributions, biology, ecology, and evolution (Kunte *et al.*, 2020).

2.1 Himalayas Butterflies: Biodiversity and Distribution

The Indian Himalayan Region (IHR) is divided into Zones 1 and 2, encompassing the Trans-Himalaya and Himalaya biogeographic zones, respectively. Zone 1 comprises the Ladakh Mountains (1A), Tibetan Plateau (1B), and Sikkim Trans-Himalaya (1C), while Zone 2 includes the North Western Himalaya (2A), Western Himalaya (2B), Focal Himalaya (2C), and Eastern Himalaya (2D) (Rodgers and Panwar, 1988; Rodgers *et al.*, 2000). Stretching approximately 3000 km in length and 400 km in width, this region spans longitudes from 70° to 96° East and latitudes from 26° to 36° North. It encompasses 12 Indian states: Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Manipur, Meghalaya, Arunachal Pradesh, Sikkim, Mizoram, Nagaland, Tripura, Assam, and West Bengal.

The North Western Himalayas have attracted numerous researchers studying the diversity, distribution, and taxonomy of butterflies. Mani and Singh, (1961, 1961a, 1962, 1962b, 1962c, and 1963) identified 77 distinct butterfly species in the North Western Himalaya. Arora, (1997) documented 80 butterfly species in the Nanda Devi habitat. Uniyal and Mathur, (1998) recorded 50 species and 34 genera in the Extraordinary Himalayan Public Park in the western Himalaya. Arora, (2000) explored the butterfly fauna of the Renuka wetland in Himachal Pradesh, while Mehta *et al.*, (2002) conducted a study on the Pong Dam wetland in Himachal Pradesh, recording 49 species, 38 genera, and 9 families. Thakur *et al.*, (2002) documented 37 butterfly species in the Himachal Pradesh sanctuary known as Kalatop-Khajjiar. Joshi *et al.*, (2008) detailed the distribution of 37 butterfly species from the western Himalayas, among 122 insect species, using six groups.

The northern Indian state of Uttarakhand, renowned for its rich biodiversity, has been a focus of research into butterfly-floral interactions (Sondhi *et al.*, 2017). Smetacek, (2012) explored the fauna and flora of Uttarakhand, recording approximately 243 butterfly species between 1951 and 2010. Qureshi *et al.*, (2013) discovered 31 butterfly species and 11 host plants in Gulmarg, Kashmir, along with various diversity indices.

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Janz and Nylin, (1998) utilized phylogenetic algorithms to investigate the relationships between butterflies and their host plants, revealing the impact of specialization and colonization on organization patterns. Rose and Sharma, (2000) conducted an in-depth analysis of *Dallacha hygriva* Moore in the Satyrid family, as well as tracking the movement of four different *Callerebia* butterflies species in the northwestern Himalayas. Rose and Sidhu, (2001) and Nijhout, (2001) created a butterfly inventory and studied the color patterns of wings of butterfly species. Bashar *et al.*, (2005) examined 22 species of Pieridae based on wing venation and identified their larval associations with various plant groups. Breuker *et al.*, (2007) conducted studies on Speckled Wood butterflies, *Pararge aegeria*, examining the relationship between eyespot integration and wing venation patterns.

Kaygin *et al.*, (2009) recorded and classified 90 species from 21 groups in Bartin, Turkey. Singh, (2009) documented 3617 butterflies from 147 species in the Kedarnath Musk Deer Reserve, Garhwal Himalaya, India, including information on seasonality, altitudinal distribution, and relative abundance. Sharma and Joshi, (2009) studied 41 butterfly species from 5 families in Dholbaha Dam, Punjab Shivalik, India. Pathania and Kumari, (2009) reported 28 species belonging to 19 genera and four families in district Una, Himachal Pradesh. Ghorpade and Kunte, (2010) reported 310 species of butterflies from the Palni hills in the South-Western Ghats of Peninsular India.

Ramesh *et al.*, (2010) described butterfly abundance and feeding activities across various habitats in the Department of Atomic Energy (DAE) campus at Kalpakkam, South India, observing 1908 individuals from 55 species across five habitat types. Nair, (2011) discovered three new butterfly species in the Similipal hills of Odisha, India. Tiple, (2011) investigated 167 species of butterflies from the Vidarbha region of Central India, categorized into 90 genera and 5 families.

Sidhu, (2011) compiled a checklist of 66 blue butterfly species (Lycaenidae) from Mussoorie and reported on the increasing biodiversity of the Himalayan ecosystem. Tiple and Ghorpade, (2012) documented 104 species of butterflies from 69 genera and 6 families in the Achanakmar-Amarkantak Biosphere Reserve in Chhattisgarh and Madhya Pradesh, including new records for 55 species. Sondhi *et al.*, (2017) reported new butterfly sightings in Jammu and Kashmir and documented 42 species in the inner Himalayas.

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Singh and Sondhi, (2016) provided an annotated checklist of 407 butterfly species in the Garhwal area. Evans, (1932) and Wynter-Blyth, (1957) reported butterfly species numbers for the Western and Eastern Himalayas. Mani, (1962, 1968) conducted substantial research on insects in the North Western Himalaya. Mani, (1986) noted that the Himalaya boasts 600 butterfly species, with 70% being mountain variants.

Kumar *et al.*, (2016) discovered 29 butterfly species in Himachal Pradesh's Chanshal Valley. Sharma and Sharma, (2017) reported two new butterfly species in Jammu and Kashmir. Sondhi *et al.*, (2017) documented 42 butterfly species in the inner Himalayas.

Arya *et al.*, (2014) recorded 897 butterflies from 27 species and 8 families in the Kumaun University region of Nainital. Kumar and Mattu, (2014) reported diverse butterfly species in Himachal Pradesh's Balh Valley. Kumar *et al.*, (2016) provided a taxonomic analysis of butterfly diversity. Despite several studies, research on the biogeographical distribution of Himalayan butterflies remains limited and scattered (Bhardwaj *et al.*, 2012).

2.2 Seasonal Influence on Butterfly Behaviour

Insect populations often display distinct seasonal patterns (Wolda and Fisk, 1981). This study delves into the significant role that the monsoon season in India plays in shaping the variety and abundance of butterflies, a phenomenon initially highlighted by Wynter-Blyth, (1957). Kunte, (1997) has also reported the prevalence of fully seasonal life cycles in many butterfly species. Worldwide research, spanning the Indian subcontinent, has investigated butterfly seasonality and its associated triggers (Arun, 2003; Padhye *et al.*, 2012; Molleman *et al.*, 2006; Pozo, 2008; Ribeiro, 2010; Srygley *et al.*, 2010; Nobre *et al.*, 2012; Singh, 2012; Valtonen, 2013; Brito *et al.*, 2014; Castro and Espinosa, 2015; Franzén *et al.*, 2017). While some studies have explored seasonal variations in butterfly species richness and abundance across altitudes (Gutiérrez and Menéndez, 1998; De Arce Crespo and Gutierrez, 2011; Despland *et al.*, 2012; Meléndez-Jaramillo *et al.*, 2019; Maicher *et al.*, 2020; Zografou *et al.*, 2020), this area of research remains relatively understudied.

Seasons exert a profound influence on most insect species, making them conducive to growth. Curiously, ecologists have historically overlooked the seasonal dynamics of

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butterflies, despite their susceptibility to seasonal fluctuations akin to other insects. Butterflies, therefore, serve as valuable indicators of habitat changes resulting from both natural and human activities. Given their sensitivity to seasonal variations in abundance and species diversity, butterflies are effective indicators of climate change (Prince-Chacón *et al.*, 2011).

Studies by Van Asch *et al.*, (2007) and Checa *et al.*, (2019) have suggested that insects thrive during specific temporal windows when ecological conditions are most favorable for their development. Additionally, the resting phase of insects has significant implications for their population dynamics. Climate change-induced variations in insect populations present a mechanism for redistributing available natural resources. Kishimoto-Yamada and Itioka, (2015) underscores the role of abiotic factors, which vary considerably in abundance, as key drivers of tropical insect populations.

Valtonen *et al.*, (2013) propose that seasonal fluctuations in insect abundance and population dynamics offer valuable insights into how insects respond to abiotic factors, including climate change. Shimadzu *et al.*, (2013) posit that longer-term environmental fluctuations, such as temperature and rainfall changes, impact species identification and abundance. Due to their relatively short lifespans, insects make excellent model organisms for studying seasonality and its correlation with changing environmental conditions. The taxonomy of butterflies has been widely embraced across all insect species (DeVries 1987, 1997; Gernaat *et al.*, 2012). Despite this, few studies, especially in tropical regions, have specifically investigated how the environment influences the development of seasonal communities. Sharma *et al.*, (2007) emphasize that any environmental factors in close proximity to a living organism can affect its lifespan.

The majority of previous studies indicate that irregularity is a common occurrence among spineless insect species, affecting their presence or absence in a given month of the year (Kunte, 2000; Davries, 2019; Maicher *et al.*, 2020; Saraf and Vijaykumar, 2021; Rani and Ahmed, 2021). Seasonal variation in species diversity and abundance is influenced by a range of abiotic factors such as temperature, precipitation, humidity, as well as biotic factors like food resource availability and vegetation. Several butterfly species adhere strictly to seasonal irregularity, appearing or

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behaving during specific times of the year, often following rainfall events.

Temperature has been consistently linked to species abundance, with higher temperatures positively affecting it, while precipitation and humidity have an inverse relationship (Hussain *et al.*, 2011). Weather patterns directly or indirectly influence the physiology of organisms in their natural environment, with temperature variations impacting developmental rates.

Furthermore, the habitat preferences of many butterfly species are directly shaped by the availability of host plants for both larvae and adults (Thomas, 1991; Dennis *et al.*, 2006). Habitat quality, in addition to food availability, influences the composition and structure of butterfly communities (Dennis *et al.*, 2003; Barlow *et al.*, 2008; Majumder *et al.*, 2012). Studies conducted in various habitat types across the globe, including India, have examined the diversity and richness of butterfly communities (Widhiono, 2015; Orimaye *et al.*, 2016; Filgueiras *et al.*, 2016; Koneri *et al.*, 2017; Norfolk *et al.*, 2017; Ohwaki *et al.*, 2017; Luppi *et al.*, 2018). However, such studies are relatively scarce in Himalayan settings (Singh and Singh, 1998; Barua, 2007; Bhardwaj *et al.*, 2012; Das *et al.*, 2012; Bora and Meitei, 2014; Nidup *et al.*, 2014; Singh, 2017a; Chettri *et al.*, 2018; Pradhan and Khaling, 2020).

2.3 Butterfly Threats

The health of India's butterfly species faces a quartet of formidable challenges, as revealed by the comprehensive "Status of India's Butterflies 2020" assessment conducted by Kunte *et al,* (2020). These threats loom large, underscoring the urgency of conservation efforts.

2.3.1. Habitat Loss and Fragmentation:

In the lush landscapes of India's Western Ghats, human-driven habitat loss and fragmentation have dealt a significant blow to butterfly populations. Vaidya *et al.*, (2019) accentuated the extent of this issue, highlighting how these activities have disrupted vital habitats. 10 years study on habitat loss and fragmentation of calcareous grassland in Europe has revealed that continuous breakdown of ecosystem can impact butterflies diversity. It also reflect the occurrence of genetic drift, which leads to over-presentation of generalist butterflies species, and loss of specialized butterflies species

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(Polus *et al.*, 2007). Habitat loss and fragmentation in the Brazilian Atlantic Forest, has found negative impact on abundance and composition of fruit feeding butterflies (Melo *et al.*, 2019). The fragmentation and loss of habitat can have detrimental consequences for both butterflies and the floral resources they depend on, ultimately reducing butterfly numbers (Van Swaay *et al.*, 2006).

2.3.2. Urbanization and Pollution

Urbanization's encroachment into butterfly habitats has brought with it a lesser-known menace-air pollution and heavy metal contamination. Urban pollutants adversely affect butterfly populations, illuminating a multifaceted threat. Study based on recolonization of Epping Forest (London, UK) depict that adult butterflies, which feed directly on sugar rich fluid oozes from the leaves or other surface of tree (*i.e.* sap runs on tree- trunks or aphid honeydew on leave surface) were more sensitive towards particulate air pollution.

Diversity of pollinators adversely affected by agricultural intensification (Potts *et al.*, 2010). India's butterfly populations face a grave peril in the form of pesticide use in agriculture and gardening. These pesticides have been implicated in diminishing both the variety and abundance of butterflies across India's agricultural landscapes (Pramanik *et al.*, 2019). 12.5% reduction in wing of adult monarch butterflies was seen as a sub-lethal response against azoxystrobin and trifloxystrobin fungicide (Olaya-Arenas *et al.*, 2020). Beyond these challenges, agricultural runoff, vehicle emissions, and industrial pollution add further st0.rain to their habitats. Gandhi and Kumar, (2013) has exposed the pernicious impact of pesticide exposure on the survival, size, and reproductive success of the Common Emigrant butterfly (*Catopsilia pomona*). India's butterfly populations are confronting a changing climate, marked by rising temperatures, shifting rainfall patterns, and unpredictable extreme weather events (Kunte, 2008). These threats, individually and collectively, cast a shadow over the well-being of butterflies in India. In light of these multifaceted perils, the preservation of India's diverse butterfly species becomes an imperative mission, necessitating a concerted effort to address these threats and ensure a flourishing future for these enchanting insects.

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2.3.3. Illegal Trade:

Several butterfly species, cherished for their beauty, rarity, or cultural significance, are ensnared in the illicit butterfly trade. The Wildlife Protection Society of India (WPSI) has uncovered the widespread nature of this illicit trade, casting a shadow over the survival of numerous species (Roy and Kumar, 2022). The illegal trade of butterflies, a nefarious practice, continues to imperil these delicate creatures. The endangered Kaiser-i-Hind butterfly (*Teinopalpus imperialis*) has not been spared, it carries high demand for illegeal traders and dealers in Nepal (Khanal, 2014) From the data obtained from Convention on International Trade in Endangered Species of wildlife flora and fauna, around more than 35 million animals were exported from 1998-2017, out of which 0.3 million were butterflies species. Unsustainable trade was found maximum in Asia continent (Nijman, 2010). Distribution of The Golden Kaiser-I-Hind (*Teinopalpus aureus* Mell) is restricted to South Asia. Illegally it sells at high price, indicating high pressure on trade markets. However, Chinas and Vietnam made some policies for its conservation, but it was found that its habitat location merely covered under protected area (Xing *et al*., 2019).

2.4. Butterflies and Flowers: Nurturing Biodiversity:

Floral resources play an indispensable role in safeguarding butterfly diversity by providing sustenance and shelter. Butterflies predominantly rely on floral nectar for sustenance while also relying on host plants for egg laying and larval development. The availability and diversity of floral resources directly influence butterfly population size and composition (Nimbalkar *et al*., 2011). Floral attributes have major impact on nector-feeding butterflies. Butterflies visit herbs and shrubs more frequently than trees. Flowers with tubular corollas are more visited than non-tubular ones, among them, yellow, blue, red and purple colored flowers were more preferred than white and pink. Availability of flower, flowering period, flower abundance also relate with butterflies diversity (Corbet, 2000). Numerous studies have delved into the intricate relationships between butterflies and floral resources, like Steffan-Dewenter and Tscharntke, (2000) illuminated a positive correlation between flower quantity and diversity within a specific region. Furthermore, the timing of butterfly emergence is intricately linked to the availability of flowers. Habel *et al*., (2016) reported that the phenology (timing of growth and reproduction) of host plants, providing nectar and

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essential nutrients, influences the date/rate of a butterfly's emergence. Additional studies have explored how flower color and fragrance influence pollinator attraction, such as Hirota *et al.*, (2012) and Ômura and Honda (2005). Cataloging nectar-producing plants for various butterfly species has been undertaken by Raju and Rao (2002) in the Visakhapatnam district. Bhuyan *et al.*, (2005) documented observations of butterfly species (*Danaus genutia*) visiting four different nectar host plant species during a 48-day period, revealing peak butterfly visitation between 11:00 and 12:00 a.m. The availability of nectar resources significantly enhances butterfly diversity and abundance, a fact corroborated by numerous studies worldwide. Knowledge of nectar-bearing plants is paramount for butterfly conservation and breeding, as noted in studies by Gillespie and Wratten, (2013), Rusman *et al.*, (2016), Shihan, (2017), and Sankaranarayanan *et al.*, (2018). Butterflies, serving as both adult pollinators and larval herbivores, can profoundly impact plant populations (Rauscher and Feeny, 1980). Lepidopteran species, including Sphingidae, Saturniidae, and Papilionidae, have well-documented larval host plants. Adult butterflies, on the other hand, exhibit versatile foraging behavior, visiting a range of accessible flowers. Kumar *et al.*, (2013) revealed that butterflies in Uttarakhand's various regions exhibit strong associations with specific host plants and nectar sources, emphasizing the profound influence of flowering plants on butterfly populations.

The phenomenon of seasonal change and its effects on butterfly populations within the Satyridae family were explored by Bashar *et al.*, (2006). Janz and Nylin, (1998) established a database on host plant relationships using evolutionary techniques to investigate various theories about the relationship between butterflies and host plants. The intricate web of interactions between butterflies and floral resources continues to be a subject of fascination and importance in the realm of biodiversity conservation and ecological studies.

This research aims to shed light on the intricate relationship between seasonal factors and butterfly behavior, unveiling the environmental intricacies that drive these fascinating creatures' life cycles and habitat preferences.

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CHAPTER-3

MATERIALS AND METHODS

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CHAPTER-3

MATERIALS AND METHODS

3.1 STUDY AREA

The present study was carried out in in district Haridwar. Its latitude is 29.58′30″ N TO 30°0.5 N, longitude is 78° 04′ 38″ to 78° 15′30″ E and altitude is 249.7 msl. District Haridwar lies in the foot hills of Shivalik ranges. Haridwar district is covering an area of approximately 2360 sq.km is in the western part of the Uttarakhand state of India.

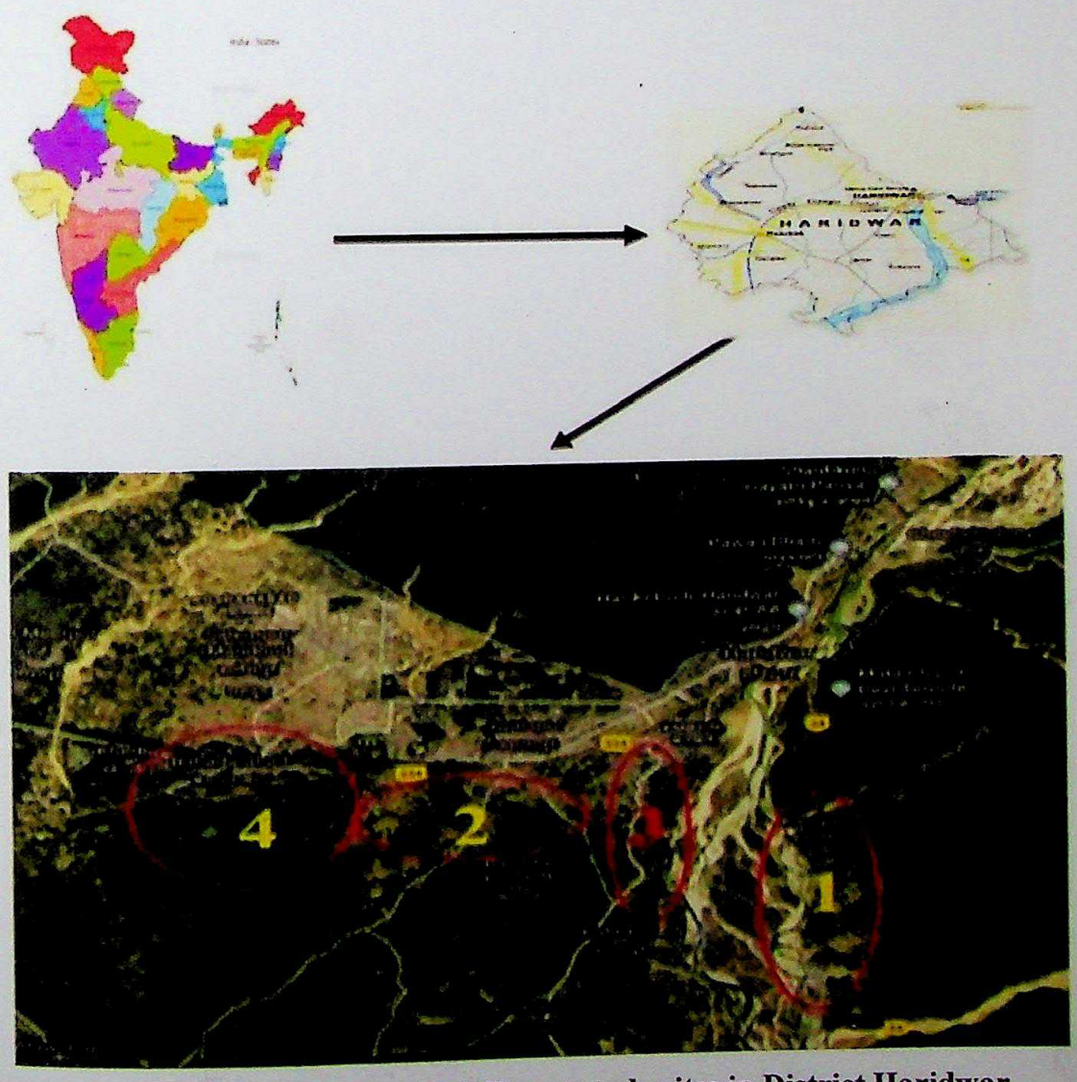

Fig. 3.1 Showing the location of different study sites in District Haridwar, Uttarakhand.

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3.2 Description of sites: - The study area was divided into 4 sites representing different types of ecosystem, i.e. Kangri (Natural forest), Jagjeetpur (Agri-horticulture), Laksar (Agriculture area), and Bahadrabad (Industrial-Barren land area).

Site I.

- It is about 7 km from main city of Haridwar situated along the banks of river Ganga. It is located at latitude 29° 55' 53" N and longitude 78° 10' 28" E.

Site II.

- This site is about 10 km from main city of Haridwar along the Haridwar-Laksar road. It is located at latitude 29° 55' 03" N and longitude 78° 08' 10" E.

Site III.

- It is an important sugar manufacturing destination in the state and is 32 km apart from main city Haridwar. Its latitude 29° 46' 12.00". N and longitude78° 02' 60.00". E, respectively.

Site IV.

- This site lies along Haridwar-Delhi highway and is about 12 Km far from main city of Haridwar. It lies between latitude 29° 55' 50" N and longitude 78° 03' 49" E.

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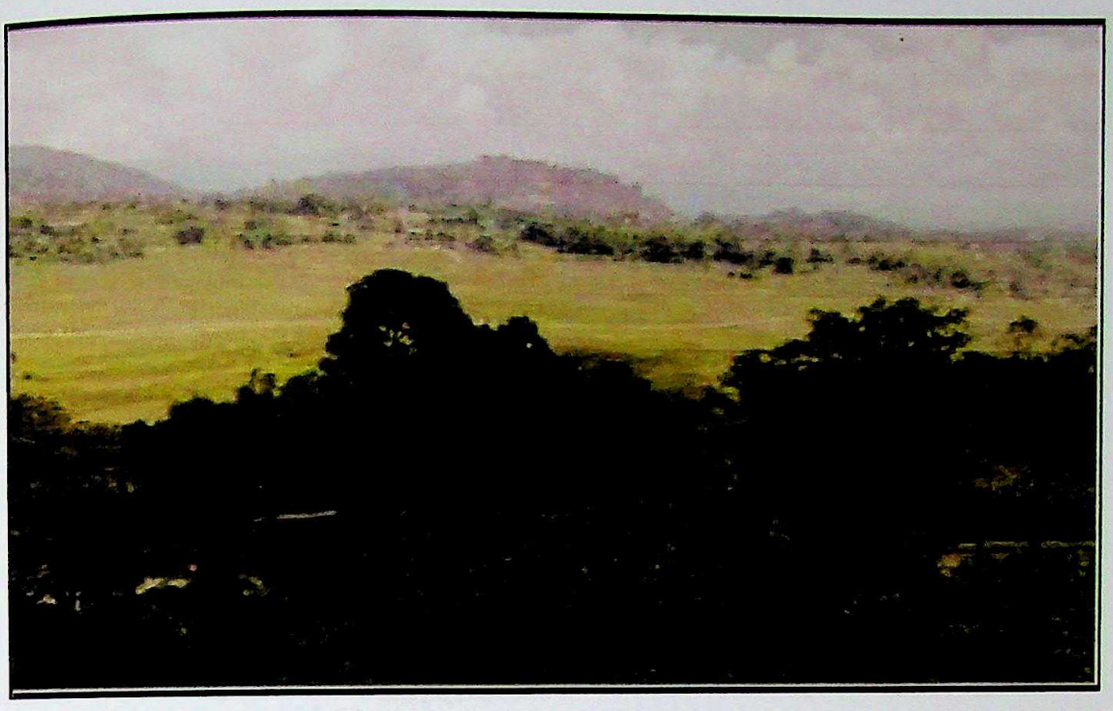

1(a)

1(b)

Photoplate: 1: (a) and (b): A view of study site I, Haridwar

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2(a)

2 (b)

Photoplate: 2: (a) and (b): A view of study site II, Haridwar

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Photoplate: 3: A view of study site III, Haridwar

Photoplate: 4: A view of study site IV, Haridwar.

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3.3 Meteorological parameters: Record of the selected meteorological parameters viz., temperature, relative humidity and rainfall were determined during the study period by using standard methods. Secondary data was also taken from the Indian Meteorological Department, Dehradun.

3.3 (a) Air Temperature (°C)

Mercury thermometer was used to measure temperature. This is the most common device, used consist of glass tube filled with mercury, which act as a working fluid. As the temperature increase, the mercury expand. Temperature is determined by measuring the volume of mercury. The S.I. unit of measured values is °C.

(b) Relative Humidity (%)

Relative humidity is measured by comparing the proportion of moisture present in air at given time with the total amount of moisture air can hold, which can differ depending on the air temperature. It was measured with the help of Hygrometer (Model name- Brass Huger Thermo Hygrometer).

(c) Rainfall (mm)

Rainfall was measured with the Rain gauge. The data was also compared with the Indian Meteorological Department, Dehradun.

3.4 Collection and identification of butterflies:

Butterflies were collected with the help of insect nets by sweeping sampling method from each respective study site on monthly basis during April 2019 to 2021 (Beall, 1935). A 100m transect was established at each site, and attempts were made to catch every butterfly seen following Pollard's transect walking technique (Pollard *et al.*, 1977; Pollard and Yates 1993). Most of the butterflies photographed at site, however those which were difficult to identify in the field, collected with the help of net. The collected specimens were transferred into the separate bottles having ethyl acetate soaked cotton at the base which helps in preservation of specimens. In the laboratory, butterflies were stretched on the wooden trays, pinned with nickel plated entomological pins No. 2 (40×0.38 mm). The specimens were oven dried and finally placed in the wooden insect boxes for identification. Most observations were recorded in the morning (08.00–12.00 noon). Identification keys used includes Kehimkar (2008); Singh and Chib (2015); Singh (2016); and Sondhi and Kunte (2018).

General identification of butterflies will also be done through the book 'The Butterflies of India' and website: <https://www.ifoundbutterflies.org/>. The

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butterflies which could not be identified in the laboratory were sent to regional station of the Zoological Survey of India (Z.S.I.), Dehradun and Entomological division of Forest Research Institute (F.R.I.), Dehradun for identification.

Photoplate 5: Showing the collection of butterflies

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3.5. Quantitative measurement of Biodiversity:

Quantitative measurement of species diversity, species richness and species evenness in different locations were made using the data derived from field surveys.

3.5.1 Species Composition: Checklist of the butterflies from each study site forest, agricultural, horticultural and barren-industrial land were prepared. Various statistical methods like Correlation Coefficient, Margalef's Index, Shannon Weiner Index, Shannon Equability Index, Simpson's Index, were used for studying the diversity and abundance of butterflies. For this purpose works of Simpson (1949), Southwood and Henderson (2009), and Khan *et al.*, (2003-04) were followed. The formula for various statistical/diversity indices are given below:

3.5.1 (a) Shannon-Weiner Index: The type of diversity that is being discussed here is E-diversity, which refers to the variety of species that exist within a community or ecosystem. The diversity index was calculated using the Shannon- Weiner diversity index from 1949.

$$H = -\sum pi \log pi$$

Where,

pi = ni/N

ni = Number of individuals of a species at time i.

N = size of whole community

(b) Simpson's Diversity Index: Simpson's Diversity Index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species.

$$D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right)$$

Where,

n = the total number of organisms of a particular species

N= the total number of organisms of all species

The value of D ranges between 0 and 1. With this index, 1 represents infinite diversity and 0, no diversity.

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(c) Shannon Equitability Index (E_H):

$$E_H = \frac{H}{log\ (k)}$$

Where,

H = Shannon –Weiner's diversity index

k = total no. of different groups (the maximum diversity)

d) Measurement of species richness: Margalef's index was used as a simple measure of species richness (Margalef's, 1958). This was calculated to know how the diversity of the population distributed or organised.

Margalef's index R = (S – 1) / ln N

Where,

S = total number of species

N = total number of individuals in the sample

ln = natural logarithm

(e) Eveness Index (J'): The evenness index (Pielou, 1969) represents the relative abundance of species in the study area.

J = H'/ln(S)

Where,

H′ = Shannon Weiner diversity

S = Number of species observed in different seasons

The J values are in the range from 0 to 1.

3.6 Record of floral resources: The floristic diversity of different kind of vegetation including trees, shrubs and herbs of the study area was carried out in different seasons during the study period. Herbarium of plants prepared which were not identified in the field, were identified with the help of experts, Botanical Survey of India, Dehradun, Department of Botany and Microbiology Gurukula Kangri (DTBU) Haridwar.

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3.7 Statistical Analysis: The collected data was calculated using Correlation Coefficient statistical tool.

3.8 Soil Sample Analysis: Soil samples were collected by using composite sampling method and the samples are analysed by procedures mentioned in Trivedi and Goel, (1984), and Anderson and Ingram (1993).

(a) Determination of Soil pH

Principle: pH is the measurement of hydrogen ions, it's based on the relative quantity of absorbed H^+ ions and metallic ions. So, soil water suspension chemical nature *i.e.* acidity and basicity easily determined through pH.

$$pH = -\log_{10} (H)^+$$

Method: Electrometric Method

Apparatus: pH meter, Balance, Glass beaker, Wash bottle

Reagents: Buffers of pH 4.0, 7.0 and 9.0

Procedure:

- 20 gm of soil sample was taken in a 250 ml of beaker, 100ml of distilled water was added in it to make 1:5 soil suspension.
- Suspension was stirred about for half an hour, at regular intervals.
- Before the measurement of pH of the sample, pH meter was calibrated by using buffers of pH 4.0, 7.0 and 9.0.
- Now the electrode of pH meter was immersed in the suspension and kept undisturbed for five minutes until the pH value become constant.

Calculations:

Take down the reading directly from the pH meter after calibration.

(b) Determination of the Organic carbon in soil.

Principle: Remains of plant materials, roots, soil organisms etc. at various stages of synthesis and decomposition represents organic matter. They can vary in composition.

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Though it occurs in relatively less amount in soil, it has a major impact on soil moisture retention, soil aggregation, available nutrient pools and biological activities

Method: Titrimetric

Apparatus: Conical flask, Pipettes, Burette, Volumetric flask, balance, Sieve, Wash bottle, Burette and Oven

Reagents

- Potassium dichromate (1N): 49.035 g of Potassium Dichromate ($K_2Cr_2O_7$) dissolved in distilled water to make 1 liter.
- Ferrous ammonium sulphate solution (0.5 N): 196.1 g of ferrous ammonium sulphate was dissolved in about 500ml of water, 20 ml of concentrated H_2SO_4 was added to it, and cooled. After that, distilled water was added to the solution to make up the final volume one liter.
- Concentrated Sulphuric acid of specific gravity 1.836.
- Orthophosphoric acid (85 %) of specific gravity 1.70 to 1.75.
- Diphenylamine Indicator Solution: 0.5 g of diphenylamine was dissolved in 20ml of distilled water. After that, 100 ml of concentrated sulphuric acid was added to the solution.

Procedure:

- 5 gm of soil sample was taken in a 500 ml conical flask, 10 ml of 1 N Potassium dichromate and 20 ml of concentrated sulphuric acid added to it.
- The mixture was thoroughly swirled for about 1 minute and allowed to stand for 30 minutes.
- 200 ml of distilled water was added slowly along with 10 ml of ortho-phosphoric acid (H_3PO_4) in the solution.
- 1 ml of diphenylamine indicator solution was added and titrate with 0.5 N ferrous sulphate until the colour changes from blue to green.

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Calculation:

$$\% \text{ Carbon} = \frac{3.951}{g} \times \frac{1-T}{S}$$

$$\% \text{ Organic Matter} = \% \text{ C} \times 1.724$$

Where,

S-Volume (ml) of FAS required for blank titration

T-Volume (ml) of FAS needed for titration of sample

g- Weight of sample in gm

(c) Determination of Moisture content of soil

Principle: Water act as solvent transporting agent in the soil. It helps in maintaining the compactness and texture of soil and thus make soil habitable for floral and faunal communities. Main soil of moisture in soil are irrigation and infiltration of precipitated water. Presence of moisture in the soil, at any time is highly depends on the type and water holding capacity of soil. However, it drains from soil through evaporation, precipitation and by plant uptake.

Apparatus: Air-tight container, Balance, Oven, Desiccator

Procedure:

- 5 gm of soil sample was taken in a dry and cleaned container.
- Soil sample and container was weighted with the help of weighing machine (W1).
- The container was placed in oven at 110°C ± 5°C for 24 h.
- After that, the container was removed and placed in dissector for cool down.
- Weight of container along with dried soil sample was taken again (W2).

Calculation:

$$\text{Soil Moisture } \% = \frac{W1-W2}{W1} \times 100$$

Where:

W_1 = Initial weight of container with 5 gm of fresh soil sample

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W_2 = Weight of container with dried soil sample

(d) Determination of Bulk density of the soil:

Principle: The ration of mass of soil to it's volume is called as bulk density or apparent density. The mass of soil can be easily determined by drying but the volume is comparatively less easy to measure accurately.

Apparatus: Container, Spatula, Weighing apparatus, Core sampler

Procedure:

- Core sampler of known volume was taken.
- The core sampler was pressed in the ground up to a desired depth by slow hammering.
- The sampler was removed along with the cylinder and the soil was removed with the help of spatula.
- The soil was placed in a clean and dried container and placed in oven at 105 °C, until a constant weight was obtained.

Calculation:

Bulk Density, g/cm^3 = $\frac{W}{V}$

W = Weight of the soil in gm

V= Volume of soil in cm^3

(e) Determination of Soil texture

Principle: Soil texture was previously determined by mechanical analysis, but now this method is replaced by particle fractionation. In this method, various particle size, which present in soil, expressed in visible proportion. Particle size above 0.02mm (fine and coarse sand), sieving technique is generally used. Soil texture analysis has significant role in soil nutrient analysis.

Method: Bouyoucos hydrometer method

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Apparatus: Heat resistant bottle, 1000 ml Beaker, Measuring cylinder, Thermometer, Buoyancy hydrometer.

Reagents: Hydrogen peroxide (30%), Amyl alcohol, Sodium hexametaphosphate

Procedure:

- 50 gm of soil weighted and added to heat resistant (105 °C) screw lid bottle, calibrated at 250 ml.
- 125 ml of distilled water added in it and the mixture was swirled thoroughly.
- 20 ml of 30% hydrogen peroxide added and bottle was swirled gently.
- A few necessary drops of amyl alcohol were added and gently swirled to minimize foaming. When the reaction has subsided, bottle was heated in the boiling water bath to complete the reaction.
- Again amyl alcohol drop wise added to contain the bubbles. After the reaction has subsided, bottle was removed from the water bath and allowed to cool.
- 2g sodium hexametaphosphate was added and volume was made up to 250 ml mark with distilled water, bottle was shook and allowed to stand for 18 hrs, *i.e.* overnight. A blank solution was also ran parallel in the same tank.
- After that, content was transferred to the 1000ml sedimentation cylinder and after distilled water washing, volume was made up to 1000ml with distilled water.
- Cylinder was placed in a water bath to maintain a constant temperature over the day.
- Cylinder was allowed to equilibrate for 30 min., the sample cylinder was mixed vigorously with a plunger and stop watch started to record time.
- Bouyoucos hydrometer readings were recorded at 40 sec. and 5 hr. After 5 hr. blank cylinder hydrometer readings and the tank temperature were also recorded.

Calculations:

40 sec. (corr) = 2(40sec. reading - 40sec. blank +T)

5hr. (corr) = 2(5 hr. reading - 5 hr. blank + T) where,

T = temperature corrections: for every °C above 20°C T = 0.3; for every °C below 29°C T= -0.3.

% sand 100-40 sec, (corr)

% silt = 40sec. (corr) - 5hr. (corr)

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% clay = 5 hr. (corr)

Where,

Sand = 2mm - 0.06mm

Silt = 0.06mm = 0.002mm.

Clay = < 0.002mm.

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CHAPTER-4

RESULTS

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CHAPTER-4

RESULTS

4.1 Floral resources available for the butterflies in the study area:

The filed survey was carried out during, 2019 to 2021, among all the study sites and a check list of the floral resources available was prepared. A total of 96 species of plants were recorded, out of which 42 were trees, 23 (Shrubs), 27 (Herbs), 03 (Climbers) and 01 (Bamboo), respectively. Table 4.1 shows the site-wise details of plant community recorded from the different study sites.

Site I

A total of 74 species of plants were recorded during the study period (2019-21) which included 36 species of trees, 14 species of shrubs, 21 species of herbs, 02 species of climbers, and 01 species of bamboo.

This site in terms of trees was mainly dominated by *Mangifera indica, Cedrela toona*, *Syzygium cumini*, *Ficus religiosa*, *Phyllanthus embilica*, *Senegalia catechu* and *Dalbergia sisso*; in terms of shrubs, the dominant species were *Murraya koenighii, Zizipus jujupa, Solanum torvum* and *Datura alba;* while in terms of herbs, the dominant species were *Ageratum conyzoides, Cannabis sativa, Parthenium hysterophorus,* and *Oplimensus burmannii.* The area was sparsely occupied by the climbers and bamboo species (Table 4.1, Fig.4.1).

Site II

A total of 70 species of plants were recorded during the study period *i.e.* 2019-21, which included 35 species of trees; 16 species of shrubs; 18 species of herbs and 01 species of climbers.

This site in terms of trees was mainly dominated by *Cedrela toona; Syzygium cumini; Phyllanthus embilica; Citrus aurantifolia; Citrus limon; Corymbia citridora* and *Mangifera indica;* in terms of shrubs, the dominant species were *Murraya koenighii*; *Zizipus jujupa*; *Desmodium ganeticum*; *Hibiscus rosa* and *Rosa indica*; in

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terms of herbs, the dominant species were *Cannabis sativa, Parthenium hysterophorus, Solanum xanthocarpum, Solanum nigrum.* The area was sparsely occupied by the climbers and bamboo species (Table 4.1, Fig. 4.2).

Site III

A total of 55 species of plants were recorded during the study period *i.e.* 2019-21, which included 23 species of trees, 13 species of shrubs; 17 species of herbs and 02 species of climbers.

This site in terms of trees was mainly dominated by *Emblica officinalis,Cedrela toona, Punica granatum, Magnifera indica* and *Corymbia citridora*; in terms of shrubs, the dominant species were *Rosa moschata, Nerium indicum, Lantana indica* and *Murraya koenighii*; in terms of herbs, the dominant species were *Ichnocarpus frutescens, Euphorbia hirta, Solanum nigrum* and *Cannabis sativa.* The area was sparsely occupied by the climbers and bamboo species (Table 4.1, Fig.4.3).

Site IV

A total of 69 species of plants were recorded during the study period *i.e.* 2019-21, which included 33 species of trees; 16 species of shrubs; 18 species of herbs; 01 species of climbers, and 01 species of bamboo, respectively.

This site in terms of trees was mainly dominated by *Mangifera indica, Corymbia citridora, Cedrela toona, Punica granatum, Phyllanthus embilica, Citrus limon* and *Dalbergia sisso*; in terms of shrubs, the dominant species were *Desmodium ganeticum, Murraya koenighii, Datura alba, Rosa indica* and *Sida rhombifolia*; in terms of herbs, the dominant species were *Ageratum conyzoides, Cannabis sativa, Solanum nigrum* and *Cyprus rotundus*. The area was sparsely occupied by the climbers and bamboo species (Table 4.1, Fig. 4.4).

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Table 4.1: Floristic composition recorded from the study sites during the study period.

S. No.	Family	Scientific Name	Common Name	Site I	Site II	Site III	Site IV
			TREES				
1.	Lauraceae	*Litsea chinensis*	Medatakdi	+	+	-	-
2.	Combretaceae	*Terminalia bellirica*	Bahera	+	+	+	+
3.	Rutaceae	*Naringi crenulata*	Toothed- leaf	+	-	-	+
4.	Meliaceae	*Toona ciliate*	Toon	+	+	+	+
5.	Myrtaceae	*Syzygium cumini*	Jamun	+	+	-	+
6.	Rutaceae	*Aegle marmelos*	Bael	+	+	-	+
7.	Rhamnaceae	*Ziziphus oenopolia*	Jackal jujube	+	+	+	+
8.	Bigoniaceae	*Oroxylum indicum*	Indian trumpet	+	+	-	+
9.	Apocynaceae	*Alstonia scholaris*	Saptaparni	-	+	-	+
10.	Moraceae	*Ficus religiosa*	Peepal tree	+	+	+	+
11.	Cannabaceae	*Celtis australis*	Khark	+	+	-	-
12.	Ulmaceae	*Hopotelea integrifolia*	Indian Elm	+	+	-	+
13.	Euphorbiaceae	*Mallotus philippensis*	Kamala	+	+	+	+
14.	Rubiaceae	Adina cordifolia	Haldu	+	-	-	-
15.	Capparaceae	*Crateva religiosa*	Temple plant	-	+	-	-
16.	Boraginaceae	*Ehretia laevis*	Chamror	+	-	-	+
17.	Combretaceae	*Anogeissus latifolia*	Dhaora	-	+	-	+

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18.	Boraginaceae	*Cordia dichotoma*	Lasoda	-	+	+	+
19.	Fabaceae	*Butea monosperma*	Palash	+	-	-	+
20.	Phllanthaceae	*Phyllanthus emblica*	Amla	+	+	+	+
21.	Fabaceae	*Senegalia catechu*	Khair	+	-	+	+
22.	Meliaceae	*Azadirachta indica*	Neem	+	+	-	+
23.	Moraceae	*Artocarpus heterophyllus*	Jack fruit	+	+	+	+
24.	Caricaceae	*Carica papaya*	Papaya	+	+	+	-
25.	Rutaceae	*Citrus aurantiifolia*	Kaghzi Nimbu	-	+	+	+
26.	Rutaceae	*Citrus limon*	Lemon	+	+	-	+
27.	Rutaceae	*Citrus maxima*	Chakotra	+	+	-	-
28.	Fabaceae	*Dalbergia sissoo*	Shisham	+	+	+	+
29.	Rosaceae	*Eriobotrya japonica*	Loquat	+	+	+	-
30.	Myrtaceae	*Corymbia citriodora*	Safeda	+	+	+	+
31.	Moraceae	*Ficus benghalensis*	Bargad	+	+	-	+
32.	Sapindaceae	*Litchi chinensis*	Lichi	+	-	-	+
33.	Anacardiaceae	*Mangifera indica*	Mango	+	+	+	-
34.	Salicaceae	*Populus alba*	White poplar	+	+	+	-
35.	Moraceae	*Morus alba*	Shahtoot	-	+	-	+
36.	Fabaceae	*Cassia fistula*	Amaltash	+	+	+	+
37.	Myrtaceae	*Psidium guajava*	Guava	+	-	+	+

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38.	Lythraceae	*Punica granatum*	Anar	+	+	+	+
39.	Rosaceae	*Pyrus Pyrifolia*	Nashpati	+	+	+	+
40.	Combretaceae	*Terminalia arjuna*	Arjun	+	+	+	+
41.	Moraceae	*Ficus racemose*	Gular	+	+	+	+
42.	Musaceae	*Musa balbisiana*	Banana	+	+	+	+
SHRUBS							
1.	Lamiaceae	*Clerodendrum infortunatum*	Bhant	+	+	+	-
2.	Rutaceae	*Murraya koenighii*	Curry leaf	+	+	+	+
3.	Rhamnaceae	*Zizipus jujupa*	Ber	+	+	+	+
4.	Lamiaceae	*Colebrookia oppositifolia*	Bhirmoli	+	-	-	-
5.	Convolvulaceae	*Ipomoea carnea*	Moon flower	-	+	+	-
6.	Solanaceae	*Solanum torvum*	Bhurat	+	+	+	+
7.	Malvaceae	*Helicteres isora*	Marorphali	-	-	+	-
8.	Fabaceae	*Desmodium ganeticum*	Shalparni	+	+	-	+
9.	Fabaceae	*Cassia occidentalis*	Kasunda	+	+	+	+
10.	Apocynaceae	*Asclepias curassavica*	Kakatundi	-	+	-	-
11.	Malvaceae	*Abutilo indicum*	Kanghi	-	+	+	+
12.	Fabaceae	*Cassia tora*	Panwar	+	-	-	+
13.	Apocynaceae	*Carissa carandas*	Karonda	-	-	+	+
14.	Solanaceae	*Datura alba*	Dhatura	+	+	-	+
15.	Malvaceae	*Hibiscusrosa-sinensis*	Gurhal	+	+	-	+

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16.	Verbenaceae	*Lantana indica*	Panjphulli	-	-	+	-
17.	Lamiaceae	*Ocimum tenuiflorum*	Tulsi	+	+	-	+
18.	Malvaceae	*Grewia asiatica*	Falsa	+	+	-	+
19.	Apocynaceae	*Nerium indicum*	Kaner	-	-	+	+
20.	Rosaceae	*Rosa indica*	Gulab	+	+	-	+
21.	Rosaceae	*Rosa moschata*	Ban gulab	-	+	+	-
22.	Malvaceae	*Sida cordata*	Bhnni Bala	+	-	+	+
23.	Malvaceae	*Sida rhombifolia*	Arrowleaf sida	-	+	-	+
HERBS							
1.	Amaranthaceae	*Achyranthus aspera*	Latjeera	+	+	+	+
2.	Asteraceae	*Ageratum conyzoides*	Goat weed	+	-	+	+
3.	Asphodelaceae	*Aloe barbadensis*	Ghee kumari	+	+	-	-
4.	Thelypteridaceae	*Ampelopteris prolifera*	Riverine Scrambler	-	-	+	+
5.	Nyctaginaceae	*Boerhavia diffusa*	Punarnava	+	+	-	-
6.	Cyperaceae	*Carex haematostoma*	Sedge	-	-	+	+
7.	Cannabaceae	*Cannabis sativa*	Bhang	+	+	+	+
8.	Menispermaceae	*Cissampelos pareira*	Laghu Patha	+	-	+	+
9.	Poaceae	*Cynodon dactylon*	Dobri	-	+	+	+
10.	Asteraceae	*Parthenium hysterophorus*	Gajar ghas	+	+	+	+
11.	Pteridaceae	*Pteris vittate*	Ladder Brake	+	-	-	-

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12.	Solanaceae	*Solanum xanthocarpum*	Kantakari	+	+	+	+
13.	Solanaceae	*Solanum nigrum*	Makoi	+	+	+	+
14.	Solanaceae	*Solanum surattense*	Choti Kateri	+	+	+	+
15.	Poaceae	*Sporobolus indicus*	Smut Grass	+	-	-	+
16.	Asteraceae	*Tagetes erecta*	Genda	-	+	+	+
17.	Urticaceae	*Urtica dioica*	Bichchhu	+	+	-	+
18.	Cyperaceae	*Cyprus rotundus*	Nut grass	+	+	+	+
19.	Dioscoreaceae	*Dioscorea bulbifera*	Air potato	-	+	-	-
20.	Fabaceae	*Tephrosia purpera*	Sarphonk	+	-	-	-
21.	Malvaceae	*Abutilon indicum*	Atibala	+	-	-	-
22.	Euphorbiaceae	*Euphorbia hirta*	Dudhi	+	+	+	+
23.	Lamiaceae	*Mentha arvensis*	Pudina	+	+	+	+
24.	Pteridaceae	*Adiantum capillus*	Venus hairfern	+	+	-	-
25.	Amaranthaceae	*Aerva sanguinolenta*	Safed phulia	-	+	-	-
26.	Poaceae	*Oplimensus burmannii*	Basket grass	+	+	+	+
27.	Apocynaceae	*Ichnocarpus frutescens*	kali dudhi	+	-	+	-
CLIMBERS							
1.	Fabaceae	*Pueraria tuberose*	Kudzu	+	-	-	+
2.	Apocynaceae	*Vallaris solanocea*	Ramsur	+	-	+	-

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3.	Smilacaceae	*Similax aspera*	Magrabu	-	+	+	-
BAMBOO							
1.	Convolvulaceae	*Cuscuta reflexa*	Bans	+	-	-	+

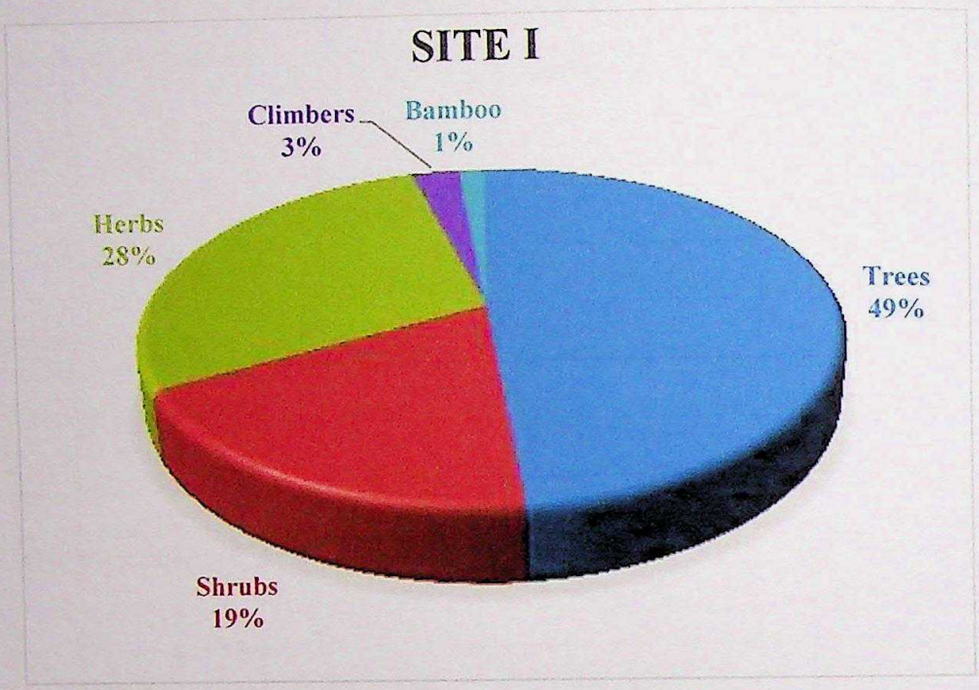

Fig. 4.1 Floral resources at site I recorded during the study period

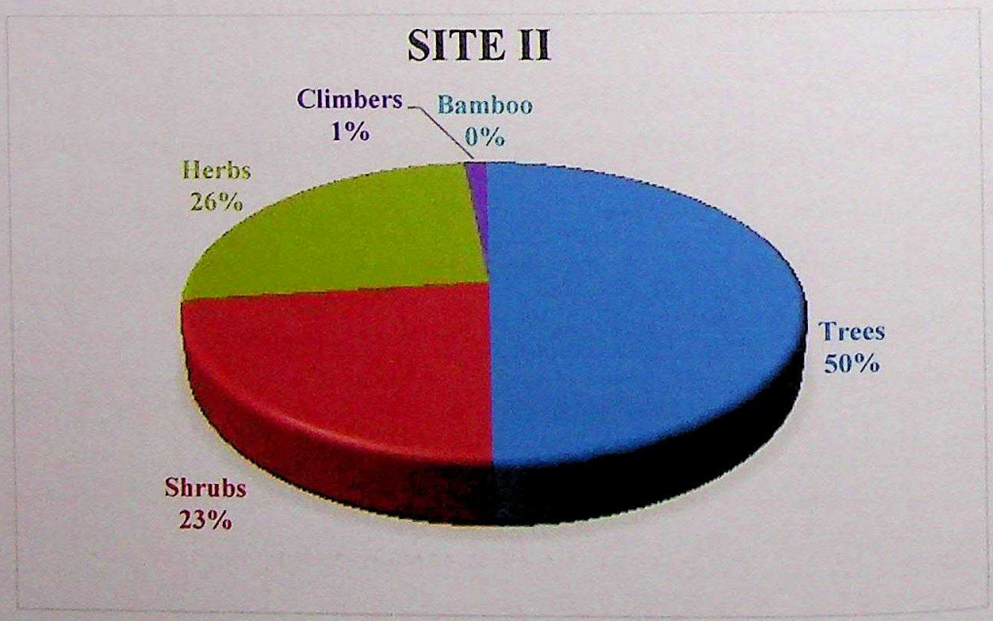

Fig. 4.2 Floral resources at site II recorded during the study period

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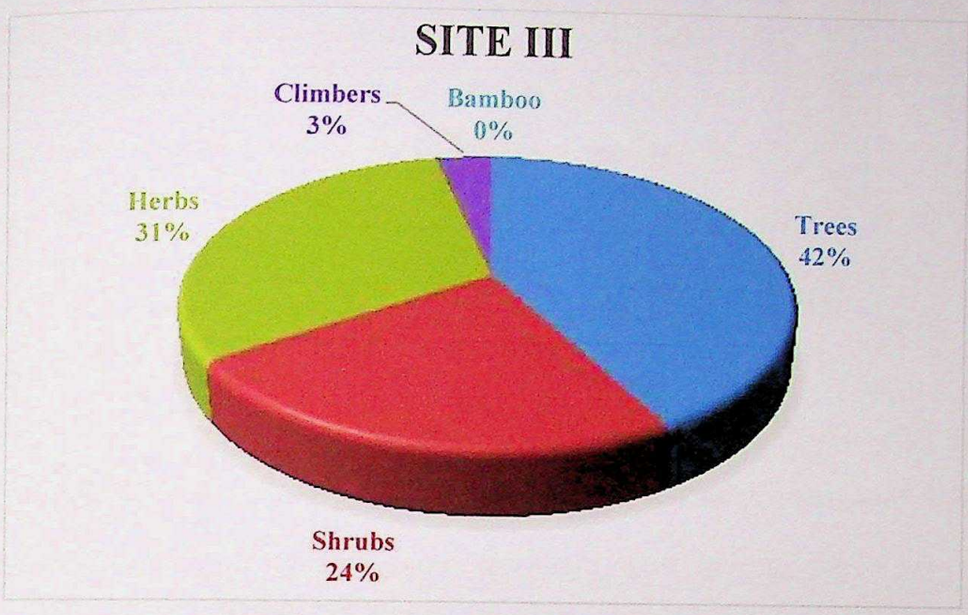

Fig. 4.3 Floral resources at site III recorded during the study period

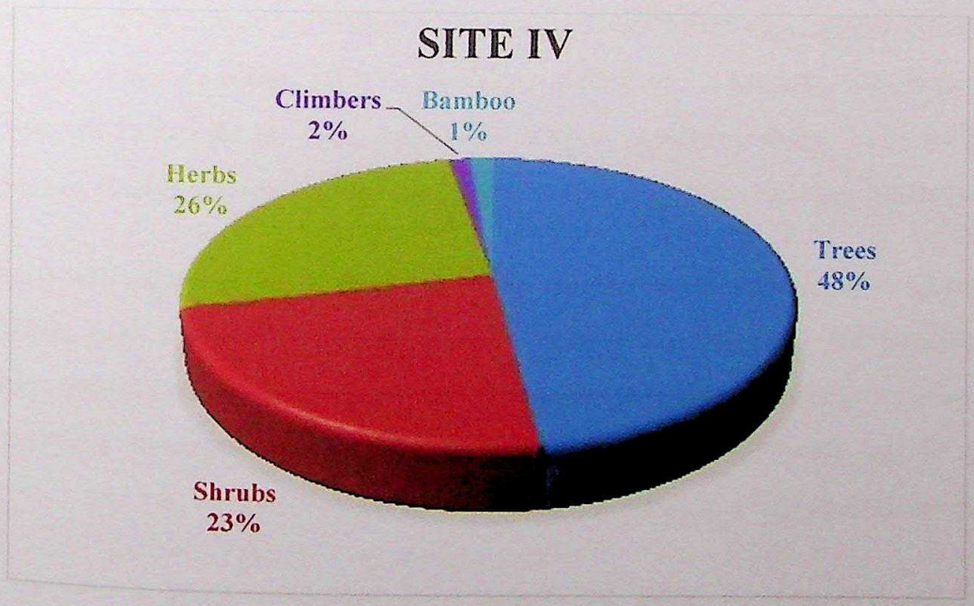

Fig. 4.4 Floral resources at site IV recorded during the study period

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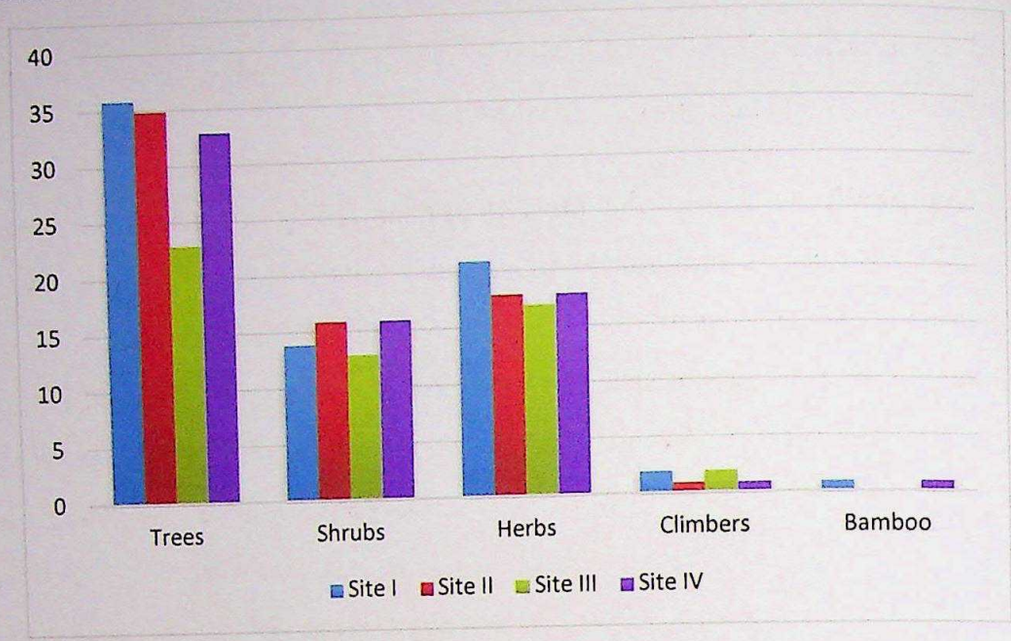

Fig. 4.5: Site-wise variations in the floral resources available for the butterflies

The results of the present study clearly presents that the floral resources were in dominant in the site I, thus provides better habitat for the butterflies (Fig. 4.5).

4.2 Taxonomic composition of Butterflies

Taxonomic composition of different species of butterflies recorded from different study sites are presented in tables (4.2 and 4.3), whereas the number of individuals of each species and relative number of species of different Lepidopteran families recorded during study period are represented in table (4.4).

During course of study a total number of 16,330 individuals of order (Lepidoptera) belonging to 90 species and 04 families were observed. Out of total individuals observed during study maximum number of species belongs to family Nymphalidae (Brush footed butterflies) (52) followed by Pieridae (White and yellow) (20), Lycaenidae (Blues) (07), and Papilionidae (Swallowtails) (05).

During the first year of study (2019-2020) the maximum number of individuals founds, to family Nymphalidae, which contributed 53.48% of total Lepidopterans followed by Pieridae (40.48%), Lycaenidae (4.01%), Papilionidae (2.03%) whereas during the second year of study (2020-2021), the maximum number of individuals belonged to family-Nymphalidae, contributing 55.88% of total Lepidopterans

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followed by Pieridae (36.67%), Lycaenidae (5.52%), while minimum in case of Papilionidae (1.92%) (Table 4.4).

Family-Nymphalidae: It was the most dominant family in terms of number of species (54) as well as individuals (8945) and contributed 54.78% to the total Lepidopterans recorded during the study period (2019-2021). *Danaus chrsippus* (Linn.) was the most abundant species of this family followed by *Telinga malsarida* (Moore), *Ariadne merione* (Cramer), *Phalanta phalantha* (Drury), *Vanessa indica* (Herbst), *Ypthimia indecora* (Moore), *Pseudergolis wedah* (Kollar), *Aglais cashmiremsis* (Kollar), *Melanitis leda* (Linn), *Junonia lemonias* (Linn.), *Vaneesa carduii* (Linn), *Neptis sankara* (Kollar), *Junonia almana* (Linn.), *Rohana parisatis* (Westwood), *Junonia orithya* (Linn) (Tables, 4.2, 4.4).

Family- Pieridae: This was the second most dominant family in terms of number of individuals (6275) and contributed 38.43% towards the total individuals. On the basis of number of species it was second dominant family with 20 species. *Eurema hecabe* (Linn.) was the most abundant species of this family followed by *Pieris canidia* (Sparrman.), *Pieris brassicae*, *Eurema laeta* (Bio.), *Catopsilia pomana* (Fab.), *Delias eucharis* (Drury), *Goneptery rhamni* (Linn.), *Eurema brigetta* (Cramer), *Colias fieldii* (Meneteris), *Appias albina* (Bio.), *Catopsilia florella* (Fab.), *Leptosia nina* (Fab.), *Pareronia hippia* (Fab.), *Aporia agathon* (Gray), *Hebomoia glaucippe* (Linn.) (Tables, 4.2, 4.4).

Family-Lycaenidae: It was the third most dominant family with 10 species and 788 individuals and contributed 4.82% to the total Lepidopterans recorded. *Zizina labradus* was the dominant species (%) followed by *Dodona durga*, *Pseudozizeeria mah, Jamides alecto* (Felder), *Virachola isocrates* (Fab), *Acytolepis puspa* (Horsfield), *Tajuria cippus* (Fabricius), *Lampides boeticus* (Linn.), *Castalius rosimon* (Fab.), *Talicada nyseus* (Guerin) (Tables, 4.2, 4.4).

Family-Papilionidae: This family was represented by 322 individuals of 06 species. *Papilio d. demolius* (Linn.) was the most abundant species and contributed to this family followed by *Graphium doson* (Felder), *Papilio protenor* (Cramer), *Papilio Polytes* (Linn.), *Graphium cloanthus* (Westwood), *P. demoleus* (Tables, 4.2, 4.4).

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Table 4.2: Number of individuals of Butterfly of order Lepidoptera collected from different sites during the study period (2019- 2021)

		2019-20					2020-21					
S. No.	Species	Site I	Site II	Site III	Site IV	Total	Site I	Site II	Site III	Site IV	Total	Grand Total
	FAMILY: NYMPHALIDAE											
1.	*Junonia orithya*	20	15	10	5	**50**	25	22	8	12	**67**	117
2.	*Melanitis leda*	40	45	25	25	**135**	50	48	22	30	**150**	285
3.	*Parantica sita*	10	0	5	10	**25**	15	0	7	20	**42**	67
4.	*Junonia almana*	35	42	27	10	**114**	38	50	30	12	**130**	244
5.	*Aglais caschimirensis*	40	48	30	25	**143**	42	49	26	28	**145**	288
6.	*Danaus chrysippus*	60	50	50	45	**205**	66	55	45	50	**216**	421
7.	*Phalanta phalantha*	50	40	45	25	**160**	54	47	50	32	**183**	343
8.	*Euploea klugii*	30	30	10	25	**95**	36	36	13	30	**115**	210
9.	*Athyma perius*	15	30	20	15	**80**	22	38	18	28	**106**	186
10.	*Athyma selenophora*	25	30	20	0	**75**	28	35	15	0	**78**	153
11.	*Junonia lemonias*	40	30	35	25	**130**	42	39	32	34	**147**	277
12.	*Ariadne merione*	35	45	50	40	**170**	38	50	54	45	**187**	357
13.	*Kallima inachus*	10	6	0	0	**16**	12	12	0	0	**24**	40
14.	*Hestinalis nama*	20	10	25	0	**55**	22	17	29	0	**68**	123
15.	*Pseudergolis wedah*	40	45	25	35	**145**	45	50	22	38	**155**	300
16.	*Neptis sankara*	35	48	40	0	**123**	38	52	34	0	**124**	247
17.	*Elymnias hypermnestra*	25	34	40	0	**99**	30	40	45	0	**115**	214
18.	*Vanessa indica*	55	40	35	20	**150**	62	44	32	30	**168**	318

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19.	*Danaus genutia*	50	40	30	35	**155**	52	50	24	39	**165**	**320**
20.	*Vanessa carduii*	45	38	30	10	**123**	48	49	35	15	**147**	**270**
21.	*Neptis yerburgi*	18	20	15	0	**53**	22	31	20	0	**73**	**126**
22.	*Phalanta alcippe*	20	14	8	0	**42**	24	21	11	0	**56**	**98**
23.	*Neptis mahendra*	25	15	10	5	**55**	28	21	15	10	**74**	**129**
24.	*Hypolimnas bolina*	10	18	12	20	**60**	15	30	14	25	**84**	**144**
25.	*Junonia atlitis*	15	20	24	12	**71**	20	29	28	18	**95**	**166**
26.	*Mycalesis perseus*	8	22	10	10	**50**	16	27	12	20	**75**	**125**
27.	*Ypthima baldus*	12	10	3	14	**39**	19	17	4	20	**60**	**99**
28.	*Eupolea core*	25	5	8	18	**56**	29	11	10	29	**79**	**135**
29.	*Vindula erota*	18	21	10	15	**64**	26	30	13	20	**89**	**153**
30.	*Eupolea mulciber*	15	8	5	10	**38**	21	12	5	15	**53**	**91**
31.	*Acraea issoria*	10	3	0	0	**13**	15	9	0	0	**24**	**37**
32.	*Charaxes bernardus*	3	0	0	2	**5**	12	0	0	8	**20**	**25**
33.	*Neptis hylas*	12	0	6	5	**23**	15	0	9	11	**35**	**58**
34.	*Euthalia aconthea*	18	6	9	0	**33**	24	12	6	0	**42**	**75**
35.	*Libythea myrrha*	8	2	0	0	**10**	10	10	0	0	**20**	**30**
36.	*Hypolimnas missipus*	20	8	12	0	**40**	23	15	18	0	**56**	**96**
37.	*Ypthima newara*	40	28	35	20	**123**	45	35	32	29	**141**	**264**
38.	*Neptis narayana*	32	25	22	15	**94**	38	32	24	22	**116**	**210**
39.	*Cyrestis thyodamas*	15	0	5	0	**20**	20	0	6	0	**26**	**46**
40.	*Rohana parisatis*	44	20	32	15	**111**	50	25	34	20	**129**	**240**

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41.	*Neptis nata*	26	12	8	18	**64**	32	22	6	24	**84**	148
42.	*Junonia hierta*	15	10	2	7	**34**	24	22	2	12	**60**	94
43.	*Junonia iphita*	30	28	15	10	**83**	35	36	22	15	**108**	191
44.	*Acraea terpsicore*	10	8	0	3	**21**	16	17	0	19	**52**	73
45.	*Parentica aglea*	30	23	19	15	**87**	34	29	23	22	**108**	195
46.	*Danaus plexippus*	18	12	4	8	**42**	22	18	8	13	**61**	103
47.	*Tirumala limniace*	20	16	8	12	**56**	28	22	10	10	**70**	126
48.	*Ypthima indecora*	50	32	41	22	**145**	56	43	46	24	**169**	314
49.	*Danaus melanippus*	5	2	0	0	**7**	8	8	0	0	**16**	23
50.	*Telinga malsarida*	60	45	40	38	**183**	64	55	48	42	**209**	392
51.	*Ypthima avanta*	15	0	10	5	**30**	21	0	12	12	**45**	75
52.	*Ypthima nareda*	12	4	8	5	**29**	18	8	6	9	**41**	70
53.	*Symbrenthia lilaea*	0	0	0	0	**0**	6	1	1	0	**8**	8
54.	*Eupolea midamus*	0	0	0	0	**0**	5	0	1	0	**6**	6
	FAMILY: PIERIDAE											
1.	*Catopsilia pomona*	50	60	45	40	**195**	57	55	42	38	**192**	387
2.	*Pareronia hippie*	35	30	40	20	**125**	39	33	38	24	**134**	259
3.	*Appias albino*	45	50	40	40	**175**	44	52	38	44	**178**	353
4.	*Cephora nerissa*	45	40	0	35	**120**	52	35	0	29	**116**	236
5.	*Belenois aurota aurota*	60	50	45	0	**155**	68	48	48	0	**164**	319
6.	*Eurema hecabe*	70	75	65	60	**270**	73	79	62	62	**276**	546

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7.	*Colias fieldii*	50	55	40	38	**183**	60	52	35	40	**187**	**370**
8.	*Pieris brassicae*	68	60	50	45	**223**	72	62	45	48	**227**	**450**
9.	*Pieris canidia*	60	62	55	50	**227**	67	65	50	48	**230**	**457**
10.	*Aporia agathon*	25	5	15	10	**55**	28	6	18	12	**64**	**119**
11.	*Colotis danae*	12	2	8	0	**22**	15	4	10	0	**29**	**51**
12.	*Hebomoia glaucippe*	10	5	0	0	**15**	12	6	0	1	**19**	**34**
13.	*Leptosia nina*	45	29	38	20	**132**	52	34	35	18	**139**	**271**
14.	*Ixias pyrene*	52	48	32	25	**157**	59	53	38	28	**178**	**335**
15.	*Eurema laeta*	72	60	40	45	**217**	77	65	48	42	**232**	**449**
16.	*Delias eucharis*	65	38	28	50	**181**	72	45	35	45	**197**	**378**
17.	*Catopsilia florella*	59	40	34	29	**162**	65	48	37	24	**174**	**336**
18.	*Pareronia valeria*	32	18	15	10	**75**	40	25	20	15	**100**	**175**
19.	*Eurema brigetta*	52	50	45	28	**175**	58	59	52	30	**199**	**374**
20.	*Gonepteryx rhamni*	60	53	29	43	**185**	66	60	25	40	**191**	**376**
FAMILY:PAPILIONOIDAE												
1.	*Papilio demoleus*	15	35	10	5	**65**	19	32	12	8	**71**	**136**
2.	*Graphium cloanthus*	5	5	0	0	**10**	3	4	1	0	**8**	**18**
3.	*Papilio protenor*	10	3	5	8	**26**	12	2	6	9	**29**	**55**
4.	*Papilio polytes romulus*	7	5	5	0	**17**	9	3	8	1	**21**	**38**
5.	*Graphium doson*	5	15	10	5	**35**	8	13	6	6	**33**	**68**
6.	*Graphium serpedon*	0	0	0	0	**0**	5	2	0	0	**7**	**7**
FAMILY:LYCAENIDAE												

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1.	*Zizina labradus*	42	40	32	30	144	55	45	42	35	**177**	321
2.	*Virachola Isocrates*	10	3	2	0	15	21	8	8	0	**37**	52
3.	*Acytolepis puspa*	8	2	0	0	10	15	5	0	1	**21**	31
4.	*Jamides Alecto*	18	9	5	2	34	24	19	9	5	**57**	91
5.	*Tajuria cippus*	3	0	1	0	4	9	0	10	0	**19**	23
6.	*Pseudozizeeria maha*	12	9	8	6	35	21	20	18	8	**67**	102
7.	*Dodona durga*	20	18	12	10	60	30	28	21	15	**94**	154
8.	*Lampides boeticus*	0	0	0	0	0	3	1	2	0	**6**	6
9.	*Talicada nyseus*	0	0	0	0	0	2	1	0	0	**3**	3
10.	*Castalius rosimon*	0	0	0	0	0	4	0	1	0	**5**	5
	Total	**2461**	**2077**	**1687**	**1308**	**7533**	**2922**	**2500**	**1807**	**1568**	**8797**	16330

Table 4.3: Taxonomic composition of Butterfly recorded from different study sites during 2019-2021

		2019-20				2020-21			
S. No.	**Species**	**Site I**	**Site II**	**Site III**	**Site IV**	**Site I**	**Site II**	**Site III**	**Site IV**
	NYMPHALIDAE								
1.	*Junonia orithya*	+	+	+	+	+	+	+	+
2.	*Melanitis leda*	+	+	+	+	+	+	+	+
3.	*Parantica leda*	+	-	+	+	+	-	+	+
4.	*Junonia almana*	+	+	+	+	+	+	+	+
5.	*Aglais caschimirensis*	+	+	+	+	+	+	+	+
6.	*Danaus chrysippus*	+	+	+	+	+	+	+	+
7.	*Phalanta*	+	+	+	+	+	+	+	+

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	phalantha								
8.	*Euploea klugii*	+	+	+	+	+	+	+	+
9.	*Athyma perius*	+	+	+	+	+	+	+	+
10.	*Athyma selenophora*	+	+	+	-	+	+	+	-
11.	*Junonia lemonias*	+	+	+	+	+	+	+	+
12.	*Ariadne merione*	+	+	+	+	+	+	+	+
13.	*Kallima inachus*	+	+	-	-	+	+	-	-
14.	*Hestinalis nama*	+	+	+	-	+	+	+	-
15.	*Pseudergolis wedah*	+	+	+	+	+	+	+	+
16.	*Neptis sankara*	+	+	+	-	+	+	+	-
17.	*Elymnias hypermnestra*	+	+	+	-	+	+	+	-
18.	*Vanessa indica*	+	+	+	+	+	+	+	+
19.	*Danaus genutia*	+	+	+	+	+	+	+	+
20.	*Vanessa carduii*	+	+	+	+	+	+	+	+
21.	*Neptis yerburii*	+	+	+	-	+	+	+	-
22.	*Phalanta alcippe*	+	+	+	-	+	+	+	-
23.	*Neptis mahendra*	+	+	+	+	+	+	+	+
24.	*Hypolimnas bolina*	+	+	+	+	+	+	+	+
25.	*Junonia atlitis*	+	+	+	+	+	+	+	+
26.	*Mycalesis perseus*	+	+	+	+	+	+	+	+
27.	*Ypthima baldus*	+	+	+	+	+	+	+	+
28.	*Eupolea core*	+	+	+	+	+	+	+	+
29.	*Nindula erota*	+	+	+	+	+	+	+	+
30.	*Eupolea mulciber*	+	+	+	+	+	+	+	+
31.	*Acraea issoria*	+	+	-	-	+	+	-	-

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32.	*Charaxes bernardus*	+	-	-	+	+	-	-	+
33.	*Neptis hylas*	+	-	+	+	+	-	+	+
34.	*Euthalia aconthea*	+	+	+	-	+	+	+	-
35.	*Libythea myrrha*	+	+	-	-	+	+	-	-
36.	*Hypolimnas missipus*	+	+	+	-	+	+	+	-
37.	*Ypthima newara*	+	+	+	+	+	+	+	+
38.	*Neptis narayana*	+	+	+	+	+	+	+	+
39.	*Cyrestis thyodamas*	+	-	+	-	+	-	+	-
40.	*Rohana parisatis*	+	+	+	+	+	+	+	+
41.	*Neptis nata*	+	+	+	+	+	+	+	+
42.	*Junonia hierta*	+	+	+	+	+	+	+	+
43.	*Junonia iphita*	+	+	+	+	+	+	+	+
44.	*Acraea terpsicore*	+	+	-	+	+	+	-	+
45.	*Parentica aglea*	+	+	+	+	+	+	+	+
46.	*Danaus plexippus*	+	+	+	+	+	+	+	+
47.	*Tirumala limniace*	+	+	+	+	+	+	+	+
48.	*Ypthima indecora*	+	+	+	+	+	+	+	+
49.	*Danaus melanippus*	+	+	-	-	+	+	-	-
50.	*Telinga malsarida*	+	+	+	+	+	+	+	+
51.	*Ypthima avanta*	+	-	+	+	+	-	+	+
52.	*Ypthima nareda*	+	+	+	+	+	+	+	+
53.	*Symbrenthia lilaea*	+	+	+	-	+	+	+	-
54.	*Eupolea midamus*	+	-	+	-	+	-	+	-
	PIERIDAE								
1.	*Catopsilia*	+	+	+	+	+	+	+	+

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	pomona								
2.	*Pareronia hippia*	+	+	+	+	+	+	+	+
3.	*Appias albina*	+	+	+	+	+	+	+	+
4.	*Cephora nerissa*	+	+	-	+	+	+	-	+
5.	*Belenois aurota aurota*	+	+	+	-	+	+	+	-
6.	*Eurema hecabe*	+	+	+	+	+	+	+	+
7.	*Colias fieldii*	+	+	+	+	+	+	+	+
8.	*Pieris brassicae*	+	+	+	+	+	+	+	+
9.	*Pieris canidia*	+	+	+	+	+	+	+	+
10.	*Aporia agathon*	+	+	+	+	+	+	+	+
11.	*Colotis danae*	+	+	+	-	+	+	+	-
12.	*Hebomoia glaucippe*	+	+	-	-	+	+	-	+
13.	*Leptosia nina*	+	+	+	+	+	+	+	+
14.	*Ixias pyrene*	+	+	+	+	+	+	+	+
15.	*Eurema laeta*	+	+	+	+	+	+	+	+
16.	*Delias eucharis*	+	+	+	+	+	+	+	+
17.	*Catopsilia florella*	+	+	+	+	+	+	+	+
18.	*Pareronia valeria*	+	+	+	+	+	+	+	+
19.	*Eurema brigetta*	+	+	+	+	+	+	+	+
20.	*Gonepteryx rhamni*	+	+	+	+	+	+	+	+
	PAPILIONOIDAE								
1.	*P. demoleus*	+	+	+	+	+	+	+	+
2.	*Graphium cloanthus*	+	+	-	-	+	+	+	-
3.	*Papilio protenor*	+	+	+	+	+	+	+	+
4.	*Papilio polytes romulus*	+	+	+	-	+	+	+	+

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5.	*Graphium doson*	+	+	+	+	+	+	+	+
6.	*Graphium serpedon*					+	+	-	-
	LYCAENIDAE								
1.	*Zizina labradus*	+	+	+	+	+	+	+	+
2.	*Virachola isocrates*	+	+	+	-	+	+	+	-
3.	*Acytolepis puspa*	+	+	-	-	+	+	-	+
4.	*Jamides alecto*	+	+	+	+	+	+	+	+
5.	*Tajuria cippus*	+	-	+	-	+	-	+	-
6.	*Pseudozizeeria maha*	+	+	+	+	+	+	+	+
7.	*Dodona durga*	+	+	+	+	+	+	+	+
8.	*lampides boeticus*	-	-	-	-	+	+	+	-
9.	*Talicada nyseus*	-	-	-	-	+	+	-	-
10.	*Castalius rosimon*	-	-	-	-	+	-	+	-

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Table 4.4: Relative number of butterfly species of different Lepidopteran families recorded different study sites during the study period (2019-2021)

S.N.	Family	2019-20				2020-21				Total no of individuals	% of Total individuals
		No. of Species	% of Species	No. of Individuals	% Individuals	No. of Species	% of Species	No. of Individuals	% Individuals		
1.	Nymphalidae	52	61.90	4029	53.48	54	60.00	4916	55.88	8945	54.78
2.	Pieridae	20	23.80	3049	40.48	20	22.22	3226	36.67	6275	38.43
3.	Papilionidae	05	5.96	153	2.03	06	6.66	169	1.92	322	1.97
4.	Lycaenidae	07	8.34	302	4.01	10	11.12	486	5.52	788	4.82
	Total	**84**	**100**	**7533**	**100**	**90**	**100**	**8797**	**100**	**16330**	**100**

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4.2.1. Monthly abundance of butterfly collected from different study sites:

In the present study, a total of 16330 individuals were collected from the selected study sites. During the first year of study (2019-2020), a total of 7533 individuals were collected, while during second year (2020-2021), 8797 individuals were collected. The monthly abundance of insects collected from different study sites has been represented in table 4.4.

Site I: During the first year of study family-Nymphalidae was the most dominant in terms of number of individuals (1339) followed by Pieridae (967), Lycaenidae (113) and Papilionidae (42). The maximum number of individuals (250) of dominant family-Nymphalidae were collected during the month of May, while minimum number of individuals (18) from family Pieridae were collected during the month of December.

During the second year of study (2020-2021), family-Nymphalidae was again found dominant order in terms of number of individuals (1606), followed by Pieridae (1076), Lycaenidae (184) and Papilionidae (56). The maximum number of individuals (280) of dominant family-Nymphalidae were collected during the month of June, while minimum number of individuals (10) from Pieridae family, and were collected during the month of December (Table 4.5, Fig. 4.6, 4.10).

Site II: At this site family-Nymphalidae was the most dominant family in terms of number of individuals (1103) during the first year of study, followed by Pieridae (830), Lycaenidae (81) and Papilionidae (63). The maximum numbers of individuals (280) of dominant family-Nymphalidae (Lepidoptera) were collected during the month of June, while the minimum number of individuals (21), from Pieridae family were collected during the month of November.

During the second year of study, Nymphalidae was the dominant family in terms of number of individuals (1606), followed by Pieridae (1076), Lycaenidae (184), Papilionidae (56). The maximum number of individuals (340) of the dominant family-Nymphalidae were collected during the month of July, while minimum number of individuals (34) of the, were collected during the month of November (Table 4.6, Fig. 4.7, 4.11).

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Site III: During the first year of study the family-Nymphalidae was the most dominant order in terms of number of individuals (933) followed by Pieridae (664), Lycaenidae (60) and Papilionidae (30). The maximum number of individuals (290) of dominant family- Nymphalidae were collected during the month of June, while minimum number of individuals (22) from Family Pieridae, and were collected during the month of November.

During the second year of study, family-Nymphalidae was dominant order in terms of number of individuals (987) followed by Pieridae (676), Danaidae (111) and Papilionidae (33). The maximum number of individuals (210) of the dominant family- Nymphalidae were collected during the month of July, while minimum number of individuals (21) of the same, were collected during the month of November (Table 4.7, Fig. 4.8, 4.12).

Site IV: This site followed the same pattern of dominance of butterfly as of site-III. During the first year of study, the family Nymphalidae was again found dominant in the order Lepidoptera, in terms of number of individuals (654), followed by Pieridae (588),Lycaenidae(48) and Papilionidae (18). The maximum number of individuals (200) of dominant family- Nymphalidae were collected during the month of June, while minimum number of individuals (19) from Family Pieridae , were collected during the month of November. During the second year of study, the family Nymphalidae was again found dominant in terms of number of individuals (892) followed by Pieridae (588), Lycaenidae (64) and Papilionidae (24). The maximum number of individuals of family-Nymphalidae (180) were collected during the month of July, while the minimum number of individuals (18) of the same were collected during the month of November. The data has been presented in (Table 4.8, Fig. 4.9, 4.13).

During the study period (2019-2020), site I was found highly dominated in terms of numbers of individuals 2461 among all four sites, followed by site II, 2077, followed by site III, 1687 and from site IV 1308. In terms of percentage followed trend was observed site I (33%) > site II (28%) > site III (22%) > site IV (17%). During the second year of study period (2020-2021) again the highest number of individuals was collected from site I (2922) and site II (2922) as compared from other sites, followed

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by site III (1807) and site IV (1568). In terms of percentage followed trend was observed site I (32%) > site II (32%) > site III (19%) > site IV (17%) (Tables, 4.5-4.8, Fig. 4.14-4.15).

Table 4.5: Monthly abundance of butterfly of different family collected from study site I during 2019-2021

	Family	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
2019-20	Nymphalidae	152	250	216	168	96	120	24	48	0	0	144	121	1339
	Pieridae	108	127	162	125	99	64	73	36	18	0	63	92	967
	Papilionidae	0	8	12	9	0	6	0	0	0	0	0	7	42
	Lycaenidae	13	12	24	12	12	0	0	0	0	0	12	28	113
	Total	**273**	**397**	**414**	**314**	**207**	**190**	**97**	**84**	**18**	**0**	**219**	**248**	**2461**
2020-21	Nymphalidae	260	240	280	200	180	120	40	20	0	20	40	206	1606
	Pieridae	150	170	190	210	116	80	30	20	10	10	0	90	1076
	Papilionidae	8	12	6	12	0	0	0	6	0	0	6	6	56
	Lycaenidae	18	54	18	36	0	18	18	0	18	0	0	4	184
	Total	**436**	**476**	**494**	**458**	**296**	**218**	**88**	**46**	**28**	**30**	**46**	**306**	**2922**

Table 4.6: Monthly abundance of butterfly of different family collected from study site II during 2019-2021

	Family	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
2019-20	Nymphalidae	185	245	280	105	70	35	35	0	35	0	0	113	1103
	Pieridae	126	147	220	115	42	42	0	21	0	0	21	96	830
	Papilionidae	0	20	10	20	0	10	0	0	0	0	0	3	63
	Lycaenidae	0	20	40	20	0	0	0	0	0	0	0	1	81
	Total	**311**	**432**	**550**	**260**	**112**	**87**	**35**	**21**	**35**	**0**	**21**	**213**	**2077**
2020-21	Nymphalidae	272	272	306	340	170	68	34	34	0	0	34	76	1606
	Pieridae	212	159	318	106	53	53	53	0	0	0	53	69	1076
	Papilionidae	8	8	24	0	8	0	0	0	0	0	0	8	56
	Lycaenidae	0	0	92	46	46	0	0	0	0	0	0	0	184
	Total	**492**	**439**	**740**	**492**	**277**	**121**	**87**	**34**	**0**	**0**	**87**	**153**	**2922**

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Table 4.7: Monthly abundance of butterfly of different family collected from study site III during 2019-2021

	Family	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
2019-20	Nymphalidae	174	232	290	116	29	0	29	0	0	0	29	34	933
	Pieridae	110	154	198	66	44	22	0	22	0	0	22	26	664
	Papilionidae	0	6	12	6	0	0	6	0	0	0	0	0	30
	Lycaenidae	7	14	21	7	0	7	0	0	0	0	0	4	60
	Total	**291**	**406**	**521**	**195**	**73**	**29**	**35**	**22**	**0**	**0**	**51**	**64**	**1687**
2020-21	Nymphalidae	168	168	189	210	105	42	21	21	0	0	21	42	987
	Pieridae	132	99	198	66	33	33	33	0	0	0	33	49	676
	Papilionidae	4	4	12	0	4	0	0	0	0	0	0	9	33
	Lycaenidae	0	0	54	27	27	0	0	0	0	0	0	3	111
	Total	**304**	**271**	**453**	**303**	**169**	**75**	**54**	**21**	**0**	**0**	**54**	**103**	**1807**

Table 4.8: Monthly abundance of butterfly of different family collected from study site IV during 2019-2021

	Family	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
2019-20	Nymphalidae	120	160	200	80	20	0	20	0	0	0	20	34	654
	Pieridae	95	133	171	57	38	19	0	19	0	0	19	37	588
	Papilionidae	0	3	6	3	0	0	3	0	0	0	0	3	18
	Lycaenidae	6	12	18	6	0	6	0	0	0	0	0	0	48
	Total	**221**	**308**	**395**	**146**	**58**	**25**	**23**	**19**	**0**	**0**	**39**	**74**	**1308**
2020-21	Nymphalidae	164	150	162	180	90	36	18	18	0	0	18	56	892
	Pieridae	116	87	174	58	29	29	29	0	0	0	29	37	588
	Papilionidae	3	3	9	0	3	0	0	0	0	0	0	6	24
	Lycaenidae	0	0	32	16	16	0	0	0	0	0	0	0	64
	Total	**283**	**240**	**377**	**254**	**138**	**65**	**47**	**18**	**0**	**0**	**47**	**99**	**1568**

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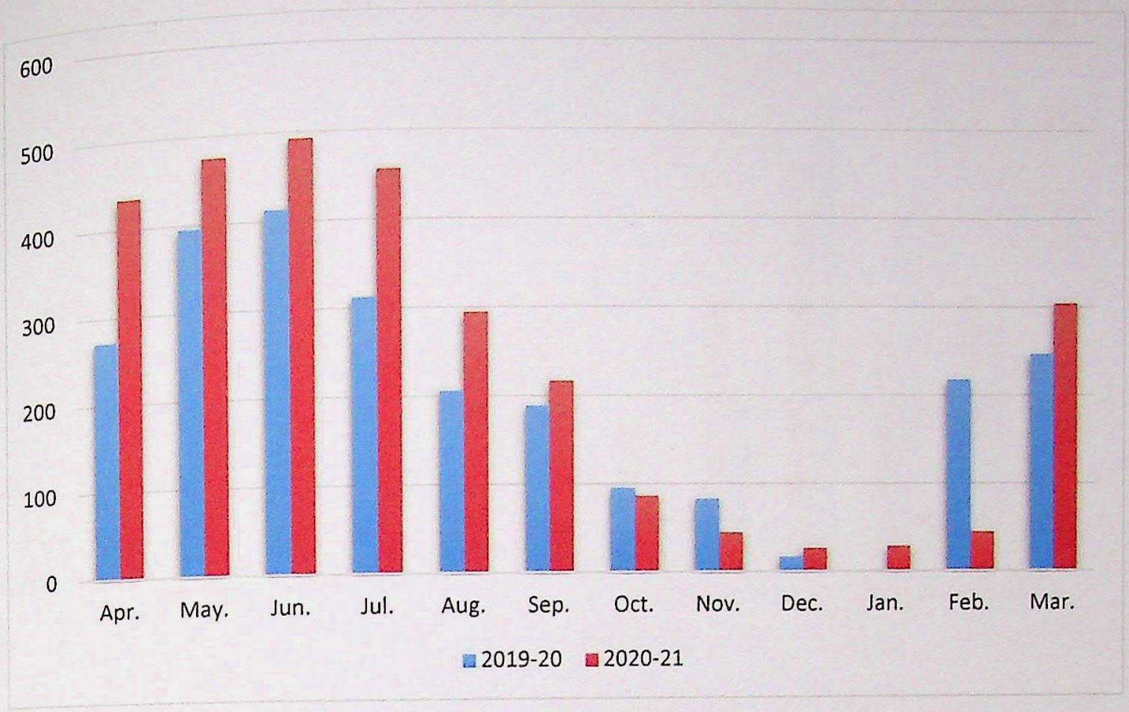

Figure 4.6: Monthly variation in number of butterflies recorded from site I during 2019-2021

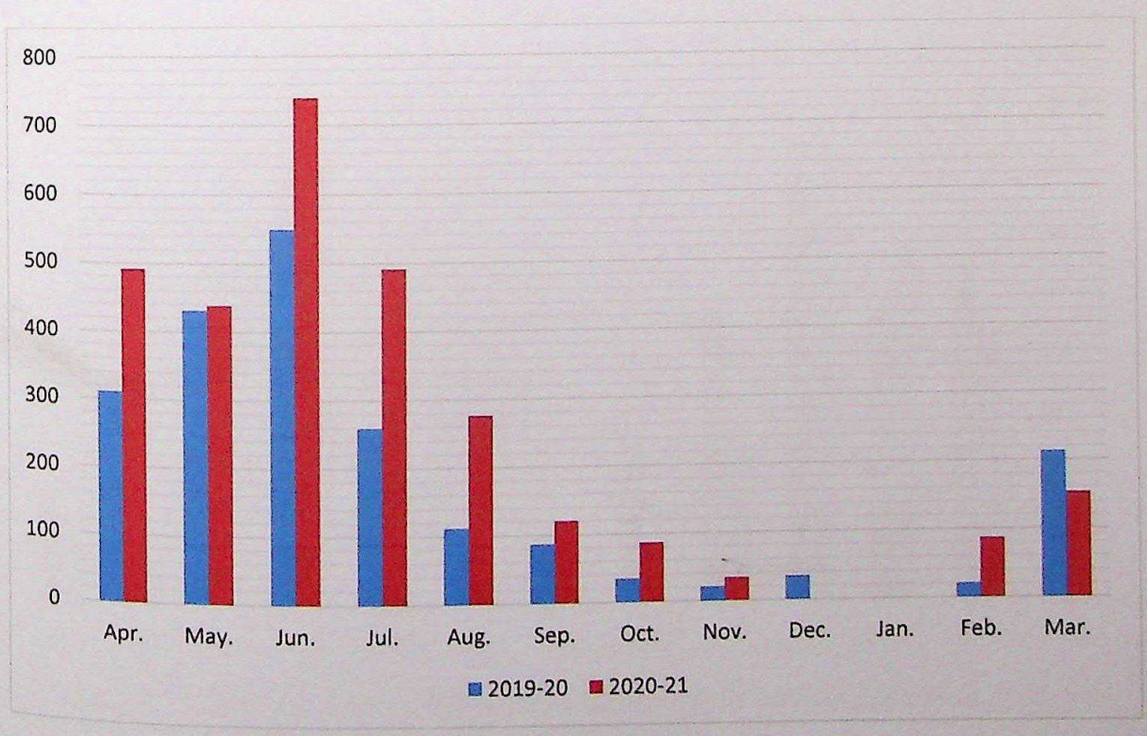

Figure 4.7: Monthly variation in number of butterflies recorded from site II during 2019-2021

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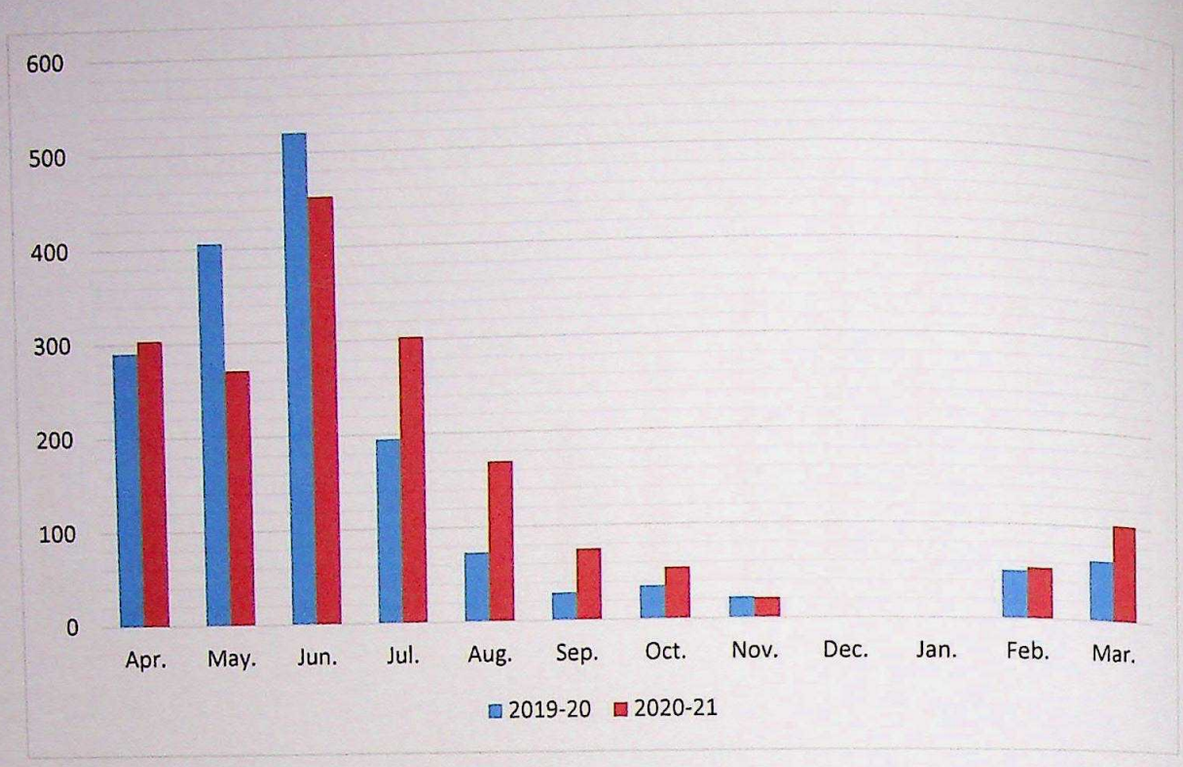

Figure 4.8: Monthly variation in number of butterflies recorded from site III during 2019-2021

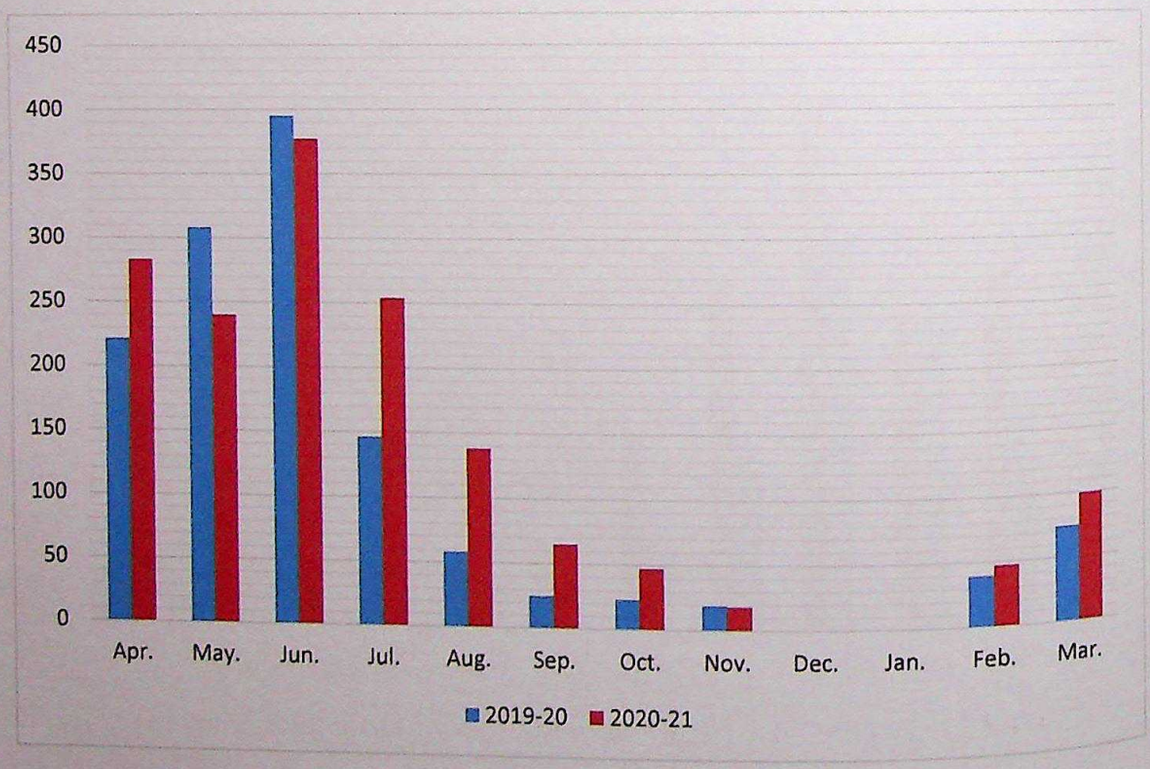

Figure 4.9: Monthly variation in number of butterflies recorded from site IV during 2019-2021

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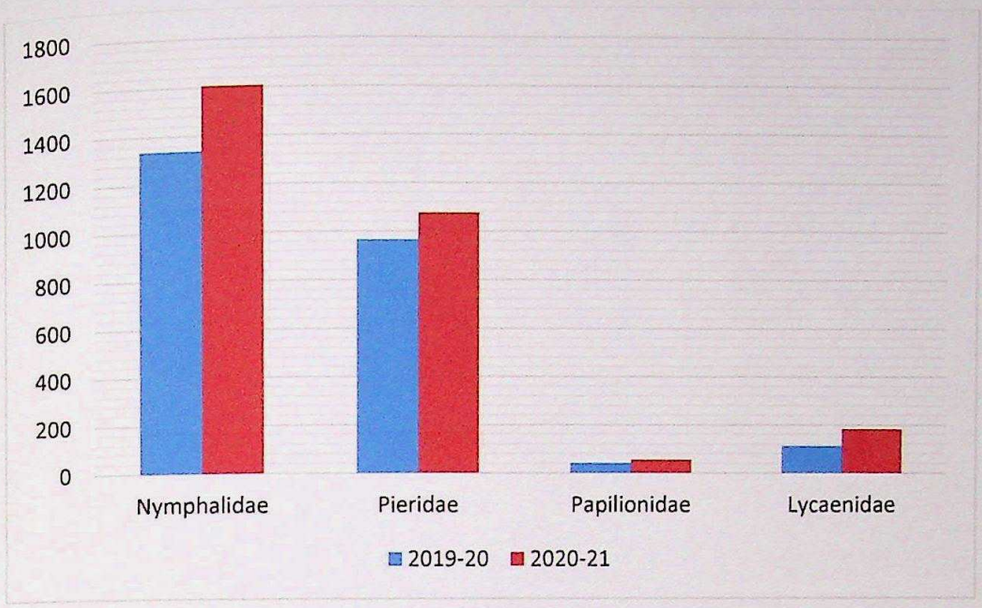

Figure 4.10: Family wise variation in number of butterflies recorded from site I during 2019-2021

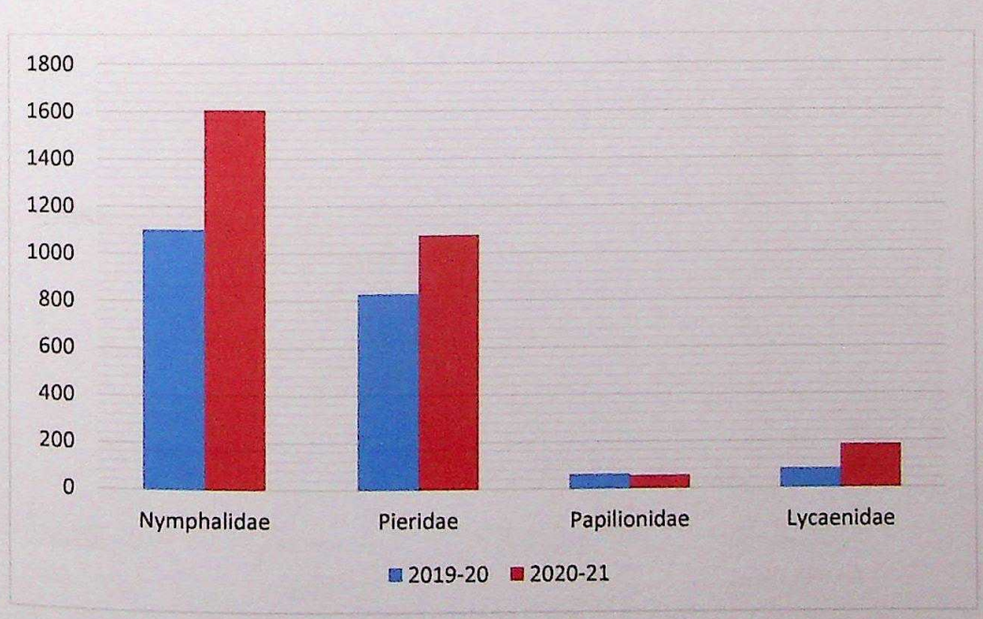

Figure 4.11: Family wise variation in number of butterflies recorded from site II during 2019-2021

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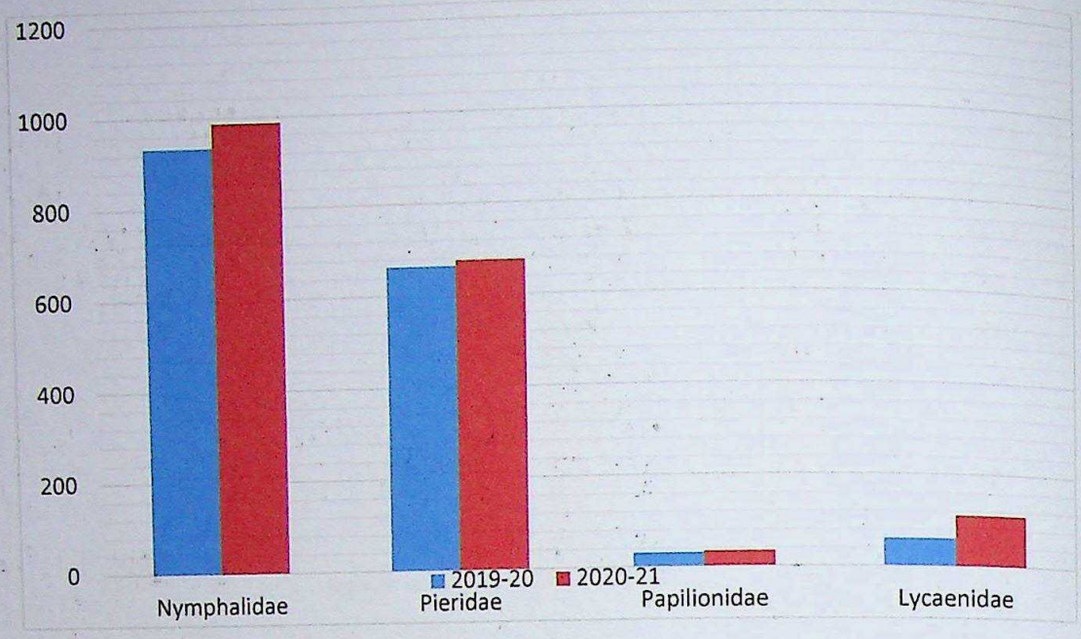

Figure 4.12: Family wise variation in number of butterflies recorded from site III during 2019-2021

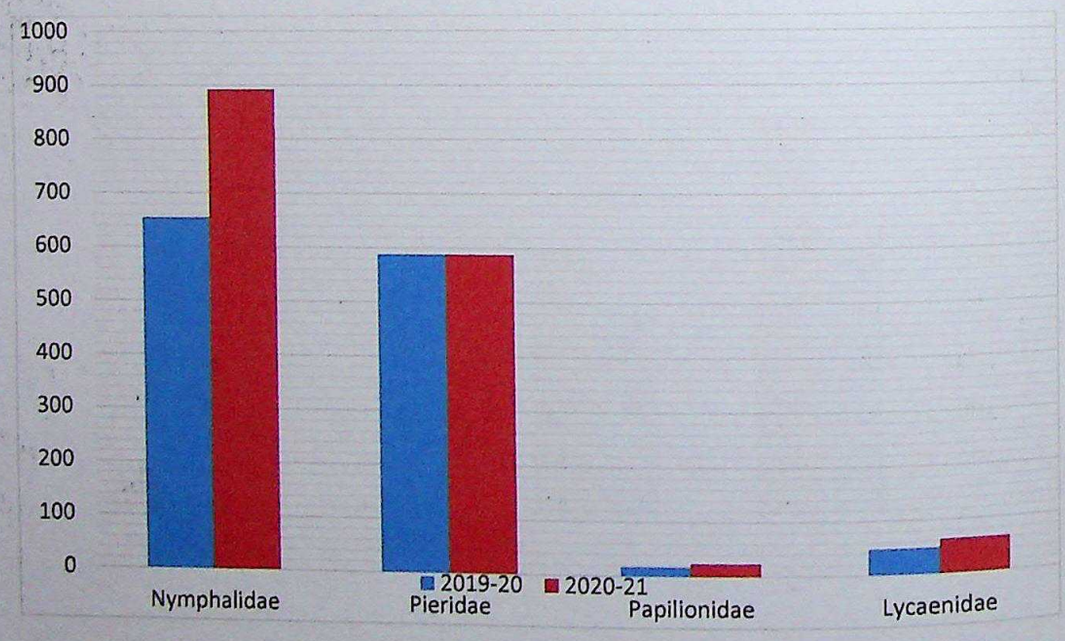

Figure 4.13: Family wise variation in number of butterflies recorded from site IV during 2019-2021

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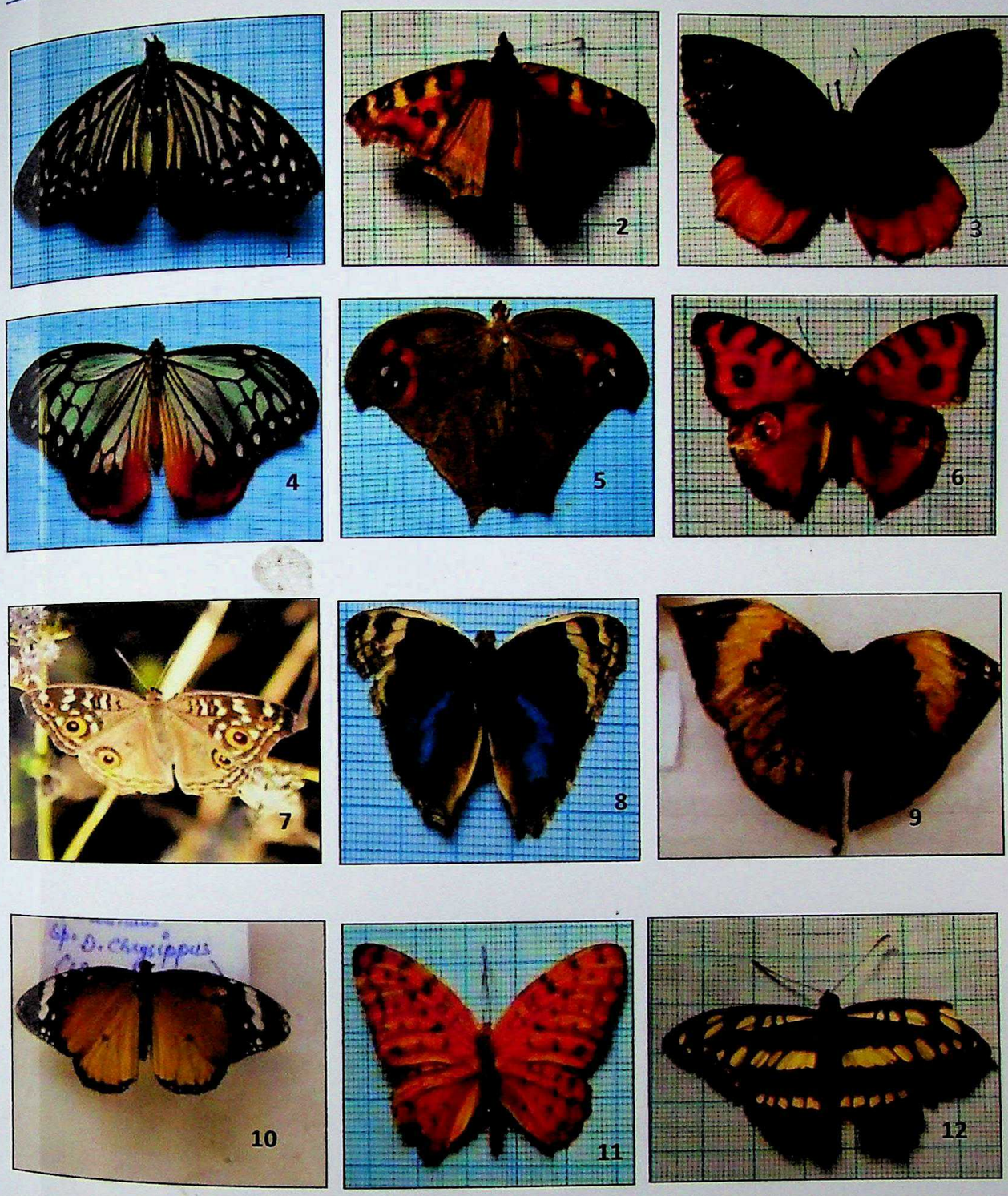

Images 1-9. 1. Hestinalis nama; 2. Aglais cashmirensis; 3. Elymnias hypermnestra; 4. Parantica sita; 5. Melantis leda; 6. Junonia almana; 7. Junonia lemonias; 8. Junonia orithya; 9. kallima inachus; 10. Danaus chrysippus; 11. Phalanta phalantha; 12. Athyma perius;

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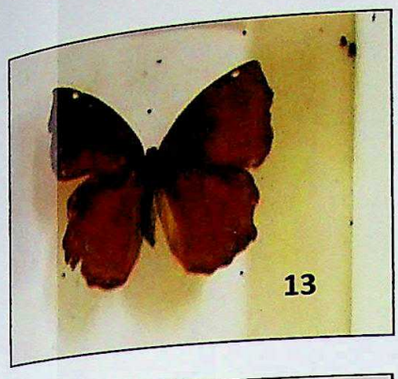

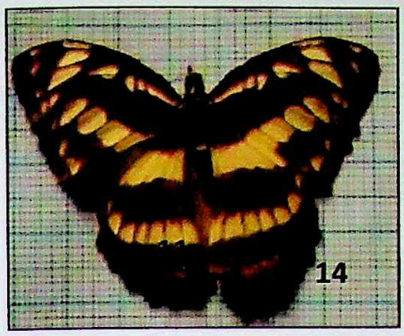

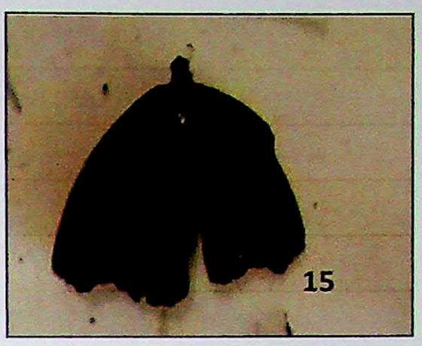

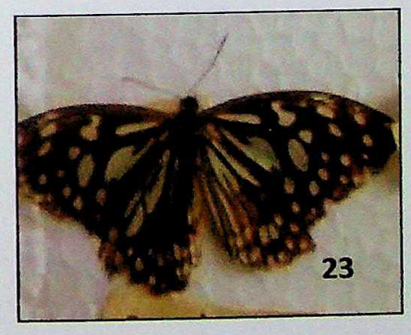

13. Ariadne merione; 14. Athyma selenophora; 15. Pseudergolis wedah; 16. Neptis sankara; 17. Vanessa indica; 18. Telinga malsarid; 19. Ypthima avanta; 20.Ypthima nareda; 21. Eupolea midamus; 22. Danaus genutia; 23. Tirumala limniace; 24. Neptis hyla;

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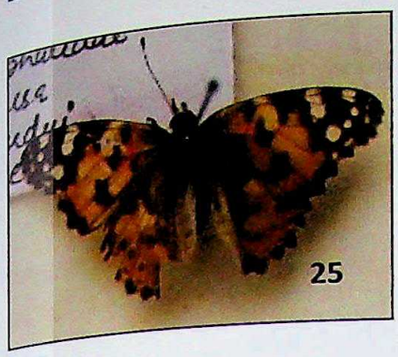

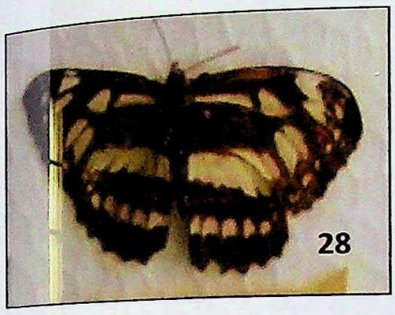

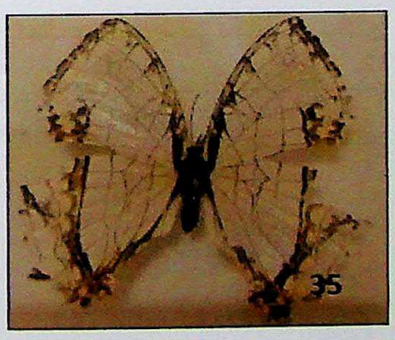

25. Vanessa carduii; 26. Junonia iphita; 27. Neptis mahendra; 28. Neptis yerburyi; 29. Hypolimnas bolina; 30. Vindula erota; 31. Acraea issoria; 32. Charaxes bernardus; 33. Libythea myrrha; 34 Ypthimia newara ; 35 Cyrestis thyodamas; 36 Neptis Narayana;

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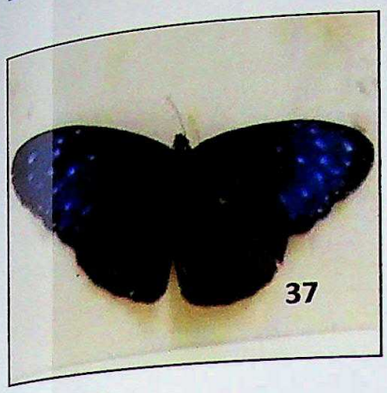

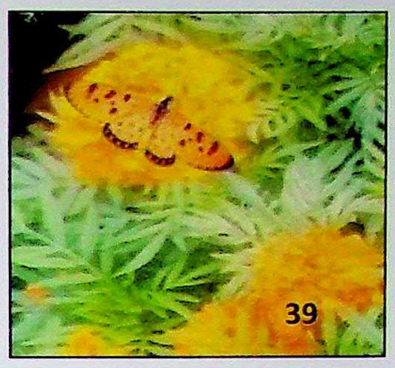

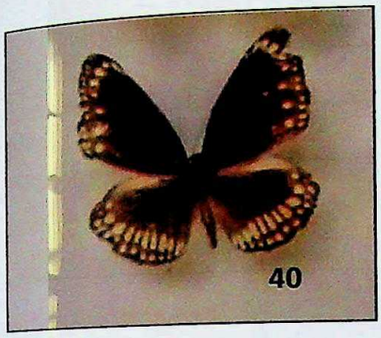

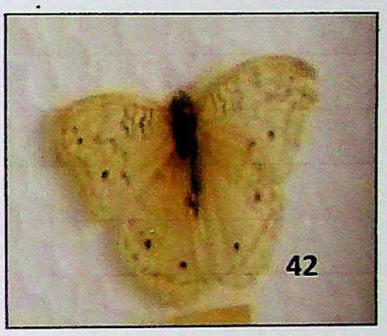

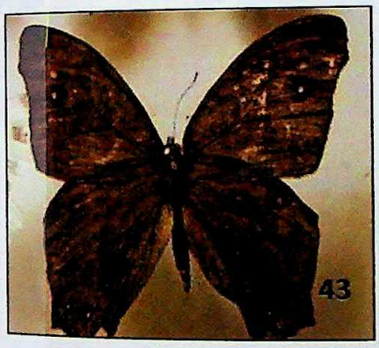

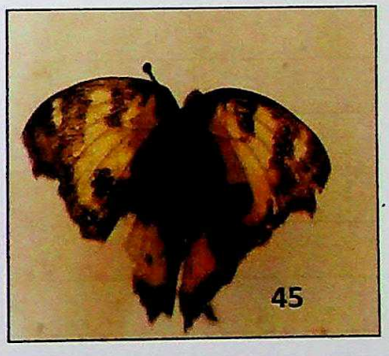

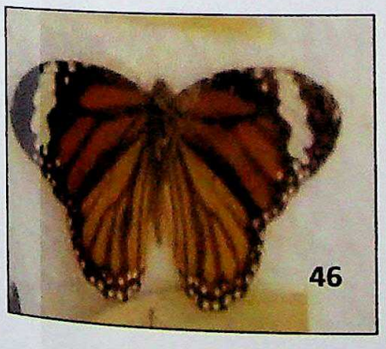

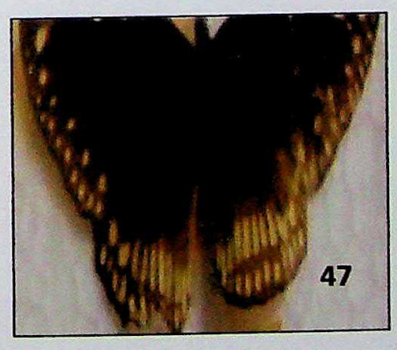

37. Eupolea mulciber; 38. Rohana parisatis; 39. Acraea terpsicore; 40. Eupolea core; 41.Ypthima indecora; 42. Junonia atlites; 43. Mycalesis perseus; 44 Euthalia aconthea; 45. Junonia hierta; 46. Danaus plexippus; 47. Eupolea klugii; 48. Danaus melanippus;

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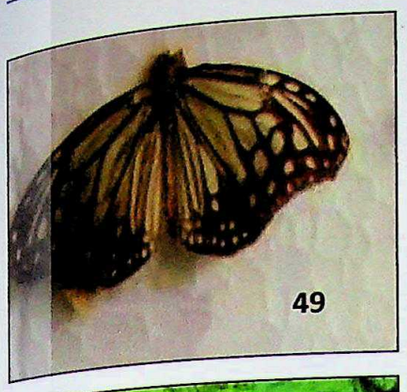

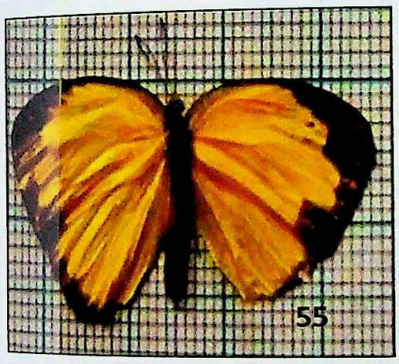

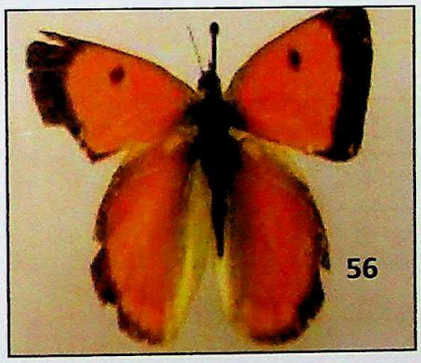

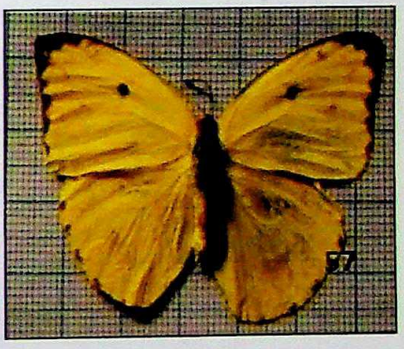

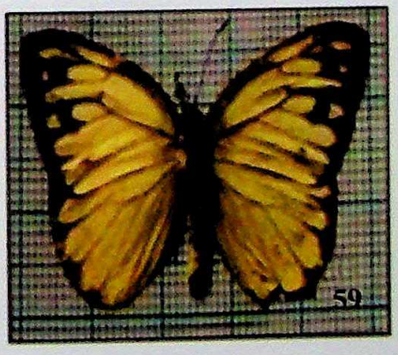

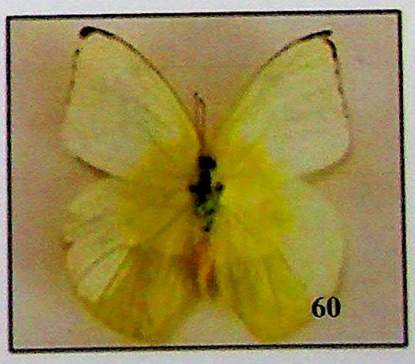

49. Parantica aglea, 50. Neptis nata, 51. Hypolimnas missipus, 52. Ypthima baldus 53. Phalanta alcippe 54. Symbrenthia lilaea, 55. Eurema hecabe, 56. Colias fieldii; 57 Appias albino, 58. Eurema laeta, 59. Cephora nerissa, 60. Catopsilia pomona , 61. Aporia agathon,

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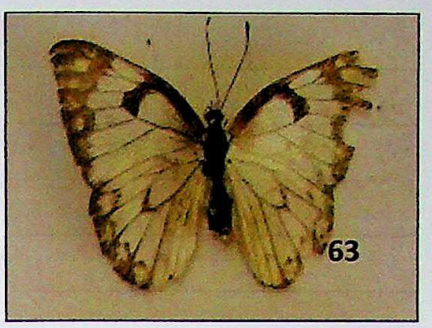

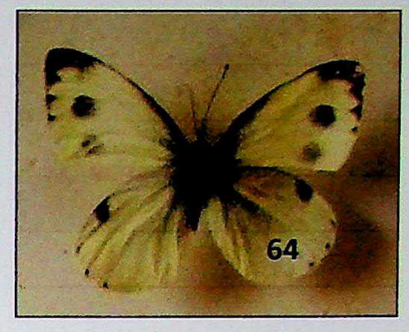

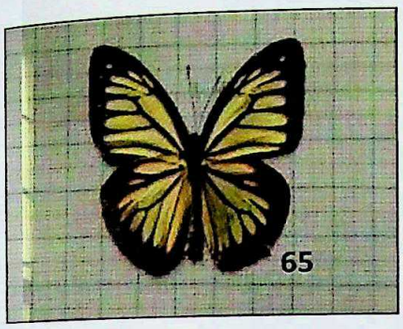

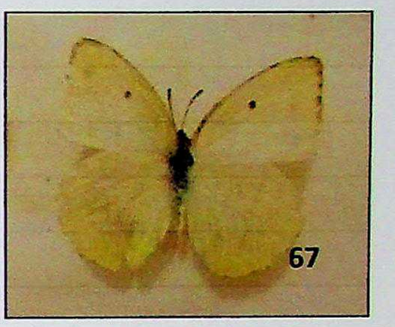

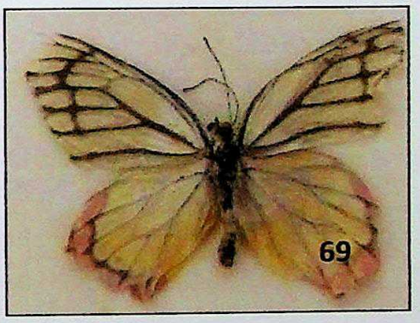

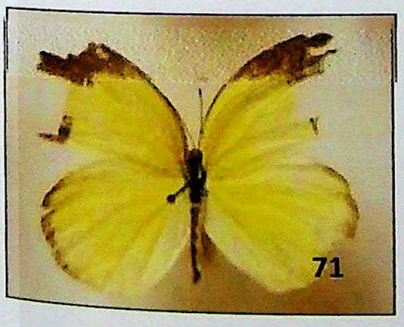

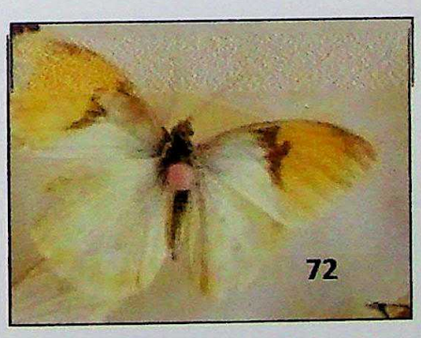

62. Ixias pyrene; 63. Belenois aurota ; 64. Pieris canidia; 65. Pareronia valaeria; 66. Leptosia nina; 67. Catopsilia florella; 68. Pareronia hippia; 69. Delias eucharis; 70. Gonepteryx rhamni; 71. Eurema brigetta; 72. Hebomoia glaucippe; 73. Colotis danae;

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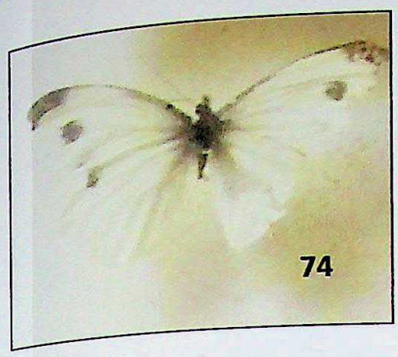

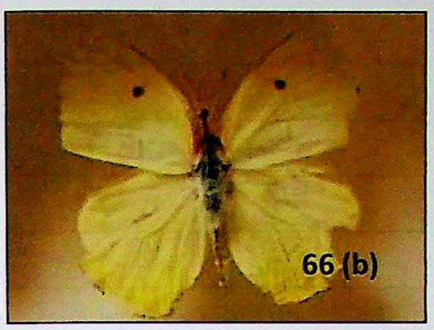

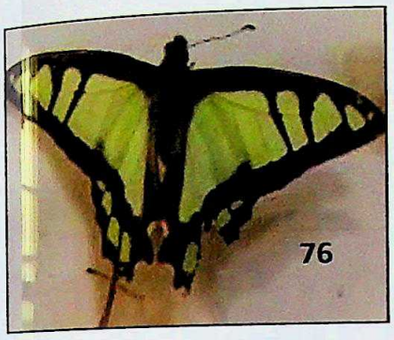

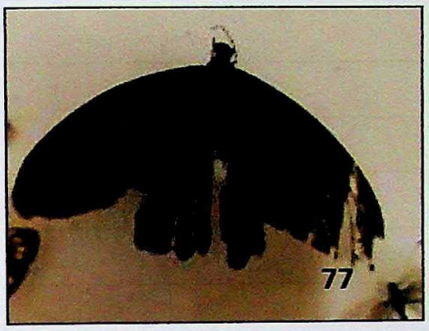

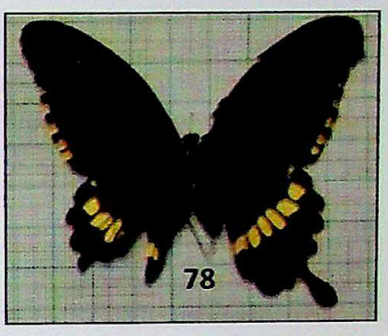

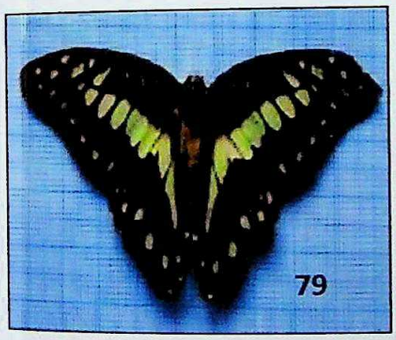

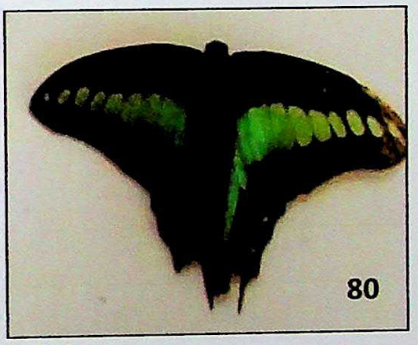

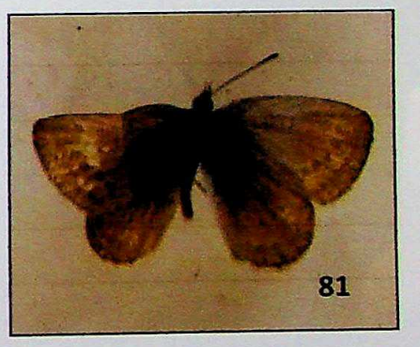

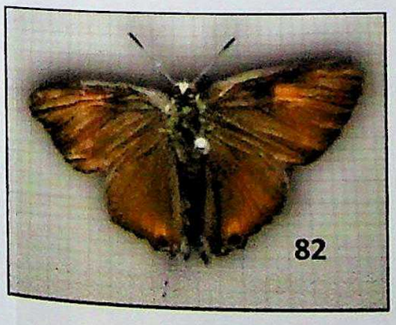

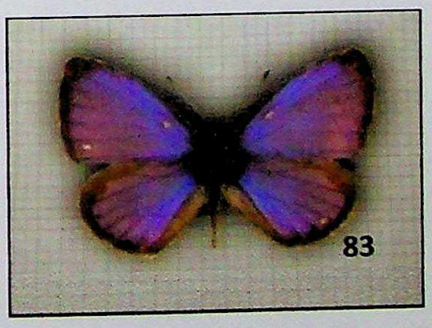

74. Pieris brassicae; 75. Papilio demoleus; 76.Graphium cloanthus; 77. Papilio protenor; 78. Papilio polytes romulus; 79.Graphium doson; 80. Graphium serpedon; 81. Zizina labradus; 82.Virachola isocrates; 83. Actolepis puspa; 84. Jamides alecto;

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85. Tajuria cippus; 86. Pseudozizeeria maha; 87. Dodona durga; 88. Lampides boeticus; 89. Talicada nyseus; 90. Castalius rosimon

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During the present study a total number of 16330 individuals belonging to 90 species, 04 families have been recorded from the different sites. Nymphalidae with 54 species was found dominant and contributed 60%of total number of species followed by Pieridae with 20 species and 22.22% total number of species, Lycaenidae (10) (11.12%), Papilionidae (06) (6.66%) and in terms of number of individuals Family Nymphalidae was again found to be the most dominant (8945) (54.78%), followed by Pieridae (6275) (38.43%),, Lycaenidae (788) (4.82%), Papilionidae (322) (1.97%) (Table 4.10).

SPECIES RICHNESS AND EVENESS OF BUTTERFLIES

Biodiversity of butterfly mainly described in terms of butterfly species diversity, mainly in terms of species richness (number of species found in a particular habitat). Butterfly species diversity is the well- organised number of diverse butterfly species that are presented in a collection of individuals. Species richness is an easy count of species, while species evenness quantify the equality in the abundance of the species. The richness and variety of a natural community can be described as diversity, whereas the ratio between number of species and importance value of individuals is called species diversity, whereas the ratio between number of species and importance value of individuals is called species diversity indices of the total number of species (Odum, 1971).

The species diversity calculated in the first and second year of study period was high in family Nymphalidae (3.77), followed by Pieridae (2.88), Lycaenidae (1.70), Papilionoidae (0.49). As shown by (Pielous index) eveness index the species eveness was high in Pieridae family (0.89), followed by Nymphalidae (0.81), Papilionoidae (0.74), Lycaenidae (0.55). In accordance with Margalefs index the species richness was high in family Nymphalidae (5.83), followed by Pieridae (2.17), Papilionoidae (0.86), Lycaenidae (0.74). As shown by Shannon equitability index, the species eveness recorded from family Nymphalidae (0.95), Pieridae (0.94), Lycaenidae (0.75), Papilionoidae (0.73). simpson diversity index also used to calculate the species richness and eveness and high value recorded from family Nymphalidae (0.97),Pieridae (0.94), Lycaenidae (0.75), Papilionoidae (0.73) (Table 4.10). The species diversity and eveness recorded at different study sites has been discussed:

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SITE I

During the two years of study period the calculated value of species diversity (H) at site I was recorded 3.80 (2019-20) and 3.87 (2020-21) from family Nmphalidae, followed by Pieridae 2.92 (2019-20) and 2.93 (2020-21), Lycaenidae 1.73 (2019-20) and 1.99 (2020-21), Papilionoidae 1.56 (2019-2020) and 1.68 (2020-21). Values of richness by using Margalef's index the high richness value recorded from Nymphalidae family 7.08 (2019-20) and 7.18 (2020-21) followed by Pieridae 2.76 (2019-20) and 2.72 (2020-21), Lycaenidae 1.26 (2019-20) and 1.72 (2020-21), Papilionoidae 1.07 (2019-20) and 1.24 (2020-21). As shown by Shannon equitability index high evenness value recorded from Nymphalidae 0.96 (2019-20) and 0.97 (2020-21), followed by Pieridae family both years have same value 0.97 (2019-2020), Papilionoidae 0.97 (2019-20) and 0.94 (2020-21), Lycaenidae 0.88 (2019-20) and 0.86 (2020-21). As shown by Simpson Diversity Index, Nymphalidae family was the most dominant in terms of species evenness and richness and both year have same value 0.97 (2019-21), followed by Pieridae again two years have the same value 0.94 (2019-21), Papilionoidae 0.71(2019-20) and 0.79 (2020-21), Lycaenidae 0.78 (2019-2020) and 0.83 (20-21) (Table 4.11).

SITE II

The Nmphalidae family had the highest calculated value of species diversity (H) at site II during the two years of the study period (2019–2021) 3.65 (2019-20) and 3.75 (2020-2021) followed by Pieridae with 2.85 (2019.20) and 2.86 (2020–21), Lycaenidae with 1.41 (2019–20) and 1.68 (2020–21), and Papilionoidae with 1.24 (2019–2020) and 1.28 (2020–21). (2020-21). When measuring richness using the Margalef's index, the Nymphalidae family had the highest richness values, 6.56 in 2019–20 and 6.46 in 2020–21, followed by Pieridae, 2.82 and 2.80, Lycaenidae, 1.13 and 1.44, and Papilionoidae, 0.96 and 1.24. (2020-21). According to Shannon's equitability index, Nymphalidae have recorded high evenness values of 0.95 (2019–20) and 0.96 (2020–21), Pieridae have recorded the same value of 0.95 (2019–2020), Lycaenidae have recorded values of 0.78 (2019–20) and 0.80 (2020–21), and Papilionoidae have recorded values of 0.77 (2019–20) and 0.71 (2020-21). Reported to Simpson Diversity Index, Nymphalidae family was the most dominant in terms of

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species evenness and richness and both year have same value 0.97 (2019-21) , followed by Pieridae 0.93 (2019-21) and 0.94 (2020-2021), Lycaenidae 0.68 (2019-20) and 0.77 (2020-21). In Family Papilionoidae both years have same value 0.62 (2019-2021) (Table 4.12).

SITE III

During the two years of study period the calculated value of species diversity (H) at site III was recorded 3.62 (2019.20) and 3.65 (2020-21) from family Nmphalidae, followed by Pieridae 2.82 (2019.20) and 2.84 (2020-21), Papilionoidae 1.38 (2019-20) and 1.49 (2020-21), Lycaenidae 1.35 (2019-2020) and 1.73 (2020-21). Values of richness by using Margalefs index the high richness value recorded from Nymphalidae family 6.58 (2019-20) and 6.81 (2020-21) followed by Pieridae 2.61 (2019-20) and 2.60 (2020-21), Lycaenidae 1.22 (2019-20) and 1.48 (2020-21), Papilionoidae 0.88 (2019-20) and 1.14 (2020-21). As shown by Shannon equitability index high evenness value recorded from Nymphalidae family both years have same value 0.94 , followed by Pieridae values of species diversity 0.97 (2019-2020) and 0.98 (2020-21), Papilionoidae 0.99 (2019-20) and 0.93 (2020-21), Lycaenidae 0.75 (2019-20) and 0.83 (2020-21). As shown by Simpson Diversity Index, Nymphalidae family was the most dominant in terms of species evenness and richness and the reported value 0.96 (2019-20) and 0.97 (2020-21), followed by Pieridae again two years have the same value 0.93 (2019-21), Papilionoidae 0.74(2019-20) and 0.76 (2020-21), Lycaenidae 0.33 (2019-2020) and 0.78 (2020-21) (Table 4.13).

SITE IV

During the two years of study period the calculated value of species diversity (H) at site IV was recorded 3.49 (2019.20) and 3.58 (2020-21) from family Nmphalidae, followed by Pieridae 2.75 (2019.20) and 2.78 (2020-21), Papilionidae1.12 (2019-20) and 1.27 (2020-21), Lycaenidae 1.04 (2019-2020) and 1.22 (2020-21). Values of richness by using Margalef's index the high richness value recorded from Nymphalidae family 5.86 (2019-20) and 5.59 (2020-21) followed by Pieridae 2.50 (2019-20) and 2.66 (2020-21), Lycaenidae 0.77 (2019-20) and 0.96 (2020-21), Papilioniidae 0.69 (2019-20) and 0.94 (2020-21). As shown by Shannon equitability index species evenness value recorded from Nymphalidae 0.95 (2019-20) and 0.97

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(2020-21), followed by Pieridae 0.97 (2019-2020) and 0.96 (2020-21), Papilionoidae 1.02 (2019-20) and 0.92 (2020-21), Lycaenidae 0.75 (2019-20) and 0.76 (2020-21). As shown by Simpson Diversity Index, Nymphalidae family was the most dominant in terms of species eveness and richness 0.96 (2019-20) and 0.97 (2020-2021), followed by Pieridae again two years have the same value 0.93 (2019-21), Papilionoidae 0.68(2019-20) and 0.71 (2020-21), Lycaenidae 0.56 (2019-2020) and 0.63 (2020-21) (Table 4.14).

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Table 4.9: Butterfly community diversity across four different study sites during 2019-21

S. N.	Site	2019-20						2020-21					
		Richness	Menhinick index	Species diversity (H')	Margalef index	Shannon Equitability index	Simpson (D) diversity index	Richness	Menhinick index	Species diversity (H')	Margalef index	Shannon Equitability index	Simpson (D) diversity index
1	Site I	84	1.69	4.23	10.63	0.95	0.98	90	1.66	4.31	11.15	0.95	0.98
2	Site II	78	1.71	4.11	10.08	0.94	0.98	82	1.64	4.20	10.35	0.95	0.98
3	Site III	74	1.80	4.07	9.82	0.94	0.98	79	1.85	4.13	10.40	0.94	0.98
4	Site IV	63	1.74	3.92	8.64	0.94	0.97	66	1.66	4.03	8.83	0.96	0.98
5	Total	299	6.94	16.33	39.17	3.77	3.91	317	6.81	16.67	40.73	3.8	3.92

Table 4.10: Total relative abundance, species composition and species diversity of butterflies recorded from different sampling sites during 2019-21

S.N.	Family	No of individuals	% of total individuals	No of species	% of species	Species diversity (H')	Evenness (J')	Margalef index	Shannon Equitability index	Simpson (D) diversity index
1	Nymphalidae	8945	54.78	54	60.00	3.77	0.81	5.83	0.95	0.97
2	Pieridae	6275	38.43	20	22.22	2.88	0.89	2.17	0.96	0.94
3	Papilionidae	322	1.97	06	6.66	1.49	0.74	0.86	0.83	0.73
4	Lycaenidae	788	4.82	10	11.12	1.70	0.55	1.34	0.74	0.75
	Total	**16330**	**100**	**90**	**100**	**9.84**	**2.99**	**10.2**	**3.48**	**3.39**

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Table 4.11: Values of species diversity indexes of butterflies at site-I during 2019-21

S. N.	Family	2019-20						2020-21					
		Richness	Abundance	Species diversity (H')	Margalef index	Shannon Equitability index	Simpson (D) diversity index	Richness	Abundance	Species diversity (H')	Margalef index	Shannon Equitability index	Simpson (D) diversity index
1	Nymphalidae	52	1339	3.80	7.08	0.96	0.97	54	1606	3.87	7.18	0.97	0.97
2	Pieridae	20	967	2.92	2.76	0.97	0.94	20	1076	2.93	2.72	0.97	0.94
3	Papilionidae	05	42	1.56	1.07	0.97	0.77	06	56	1.68	1.24	0.94	0.79
4	Lycaenidae	07	113	1.73	1.26	0.88	0.78	10	184	1.99	1.72	0.86	0.83
5	Total	84	2461	10.01	12.17	3.78	3.46	90	2922	10.47	12.86	3.74	3.53

Table 4.12: Values of species diversity indexes of butterflies at site-II during 2019-21

S. N.	Family	2019-20						2020-21					
		Richness	Abundance	Species diversity (H')	Margalef index	Shannon Equitability index	Simpson (D) diversity index	Richness	Abundance	Species diversity (H')	Margalef index	Shannon Equitability index	Simpson (D) diversity index
1	Nymphalidae	47	1103	3.65	6.56	0.95	0.97	48	1606	3.75	6.46	0.96	0.97
2	Pieridae	20	830	2.85	2.82	0.95	0.93	20	1076	2.86	2.80	0.95	0.94
3	Papilionidae	05	63	1.24	0.96	0.77	0.62	06	56	1.28	1.24	0.71	0.62
4	Lycaenidae	06	81	1.41	1.13	0.78	0.68	08	184	1.68	1.44	0.80	0.77
5	Total	78	2077	9.15	11.47	3.45	3.2	82	2922	9.57	11.94	3.42	3.30

Table 4.13: Values of species diversity indexes of butterflies at site-III during 2019-21

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Table 4.13: Values of species diversity indexes of butterflies at site-III during 2019-21

S. N.	Family	2019-20						2020-21					
		Richness	Abundance	Species diversity (H')	Margalef index	Shannon Equitability index	Simpson (D) diversity index	Richness	Abundance	Species diversity (H')	Margalef index	Shannon Equitability index	Simpson (D) diversity index
1	Nymphalidae	46	933	3.62	6.58	0.94	0.96	48	987	3.65	6.81	0.94	0.97
2	Pieridae	18	664	2.82	2.61	0.97	0.93	18	676	2.84	2.60	0.98	0.93
3	Papilionidae	04	30	1.38	0.88	0.99	0.74	05	33	1.49	1.14	0.93	0.76
4	Lycaenidae	06	60	1.35	1.22	0.75	0.33	08	111	1.73	1.48	0.83	0.78
5	Total	74	1687	9.17	11.29	3.65	2.96	79	1807	9.71	12.03	3.68	3.44

Table 4.14: Values of species diversity indexes of butterflies at site-IV during 2019-21

S. N.	Family	2019-20						2020-21					
		Richness	Abundance	Species diversity (H')	Margalef index	Shannon Equitability index	Simpson (D) diversity index	Richness	Abundance	Species diversity (H')	Margalef index	Shannon Equitability index	Simpson (D) diversity index
1	Nymphalidae	39	654	3.49	5.86	0.95	0.96	39	892	3.58	5.59	0.97	0.97
2	Pieridae	17	588	2.75	2.50	0.97	0.93	18	588	2.78	2.66	0.96	0.93
3	Papilionidae	03	18	1.12	0.69	1.02	0.68	04	24	1.27	0.94	0.92	0.71
4	Lycaenidae	04	48	1.04	0.77	0.75	0.56	05	64	1.22	0.96	0.76	0.63
5	Total	63	1308	8.4	9.82	3.69	3.13	66	1568	8.85	10.15	3.61	3.24

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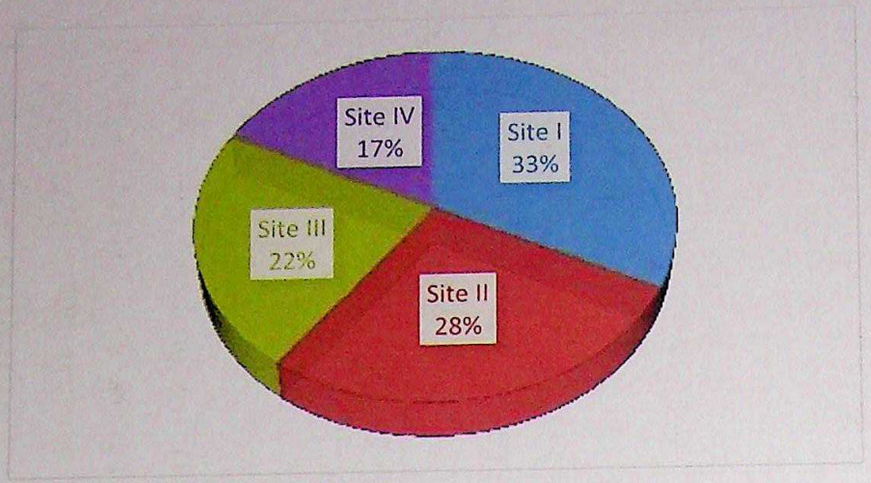

Fig 4.14: Total % of individuals reported at different study sites during 2019-20

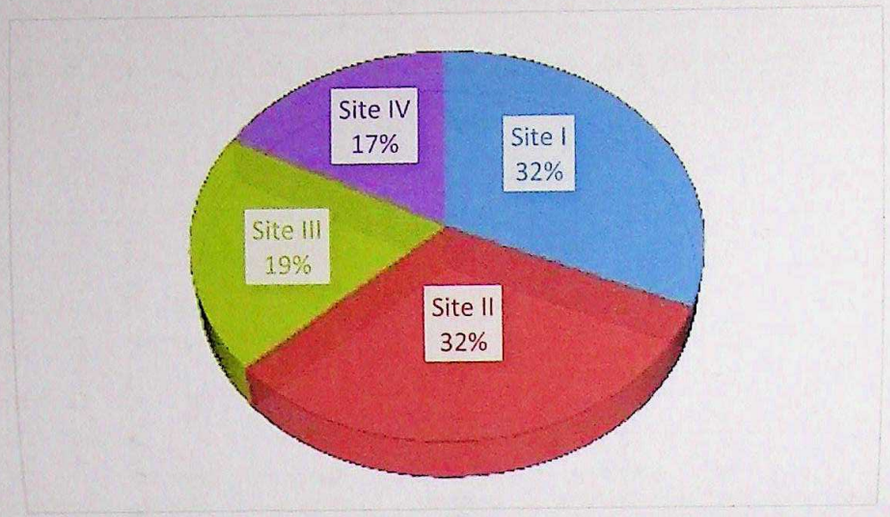

Fig 4.15: Total % of individuals reported at different study sites during 2020-21

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ATMOSPHERIC TEMPERATURE AND HUMIDITY

The distribution of butterflies is greatly influenced by environmental conditions like temperature, humidity, and precipitation. Their activity levels and developmental rates are influenced by temperature, with various species adapting to various temperature ranges. Particularly in arid or humid regions, humidity reduces their capacity to retain body moisture. The availability of flowers that provide nectar and host plants that are essential for butterfly survival are influenced by rainfall patterns. These elements work together to determine whether a region is suitable for a particular species of butterfly, making butterflies important indicators of the health of the environment and the effects of climate change.

TEMPERATURE (°C)

During the first year of study (2019-2020) the minimum and maximum temperature recorded from the different sites have been given in the (Tables 4.15, Fig.4.20). The minimum temperature during 2019-20 was observed in the month of January, as followed, 19.96 ± 1.05 (site I), 21.29 ± 1.43 (site II), 21.55±1.20 (site III), 21.66±1.08 (site IV). Similarly the maximum temperature recorded was in the month of June from all the four sites and the values are 42.93±0.11 (site I), 43.35±0.50 (site II), 43.42±1.17 (site III), and 42.89±1.66 (site IV).

During the second year of study (2020-2021) the minimum and maximum temperature noticed from the four different sites have been given in the (Table 4.16, Fig 4.25). The minimum temperature recorded was in the month of January from all the four sites and the values were 23.28±1.18 (site I), 24.39±0.96 (site II), 24.29±1.18 (site III), and 24.25±0.54 (site IV). In the same way maximum temperature recorded was in the month of June from three sites and the values recorded were 40.74±0.69 (site I), 41.22±1.29 (site II), and 4.028±1.16 (site III). However, for the site IV the maximum value was recorded in the month of May and the value are 41.30±1.20.

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HUMIDITY (%)

The minimum and highest humidity values observed from all four sites during the first year of the study period (2019-2020) are listed in the table below. May was the month with the lowest humidity readings at all four sites, and the value were16.69±0.63 (site I), 17.02±0.13 (site II), 17.39±0.74 (site III), and 17.65±1.17 (site IV). All four sites reported their highest humidity levels in September and the values are: 78.26±1.52 (site I), 78.83±1.60 (site II), 79.11±1.14 (site III), 79.38±0.74 (site IV) (Table 4.17, Fig. 4.30).

During the second year of study the base and most extreme humidity recorded from every one of the four sites have been given in the (Table 4.18, Fig.4.35). The minimum humidity reported for all the four sites in the month of March and the recorded values were 20.12±0.30 (site I), 21.13±0.07 (site II), 21.30±1.21 (site III), and 21.02±0.71 (site IV). August was the month with highest level of reading from all four sites and the values are 78.19±1.04 (site I), 79.10±0.21 (site II), 79.13±0.22 (site III), and 78.78±1.68 (site IV).

RAINFALL (mm)

During the two years of study period (2019-2020) the minimum rainfall recorded was in the month of November from all the four sites and the readings were 6.83±0.26 (site I), 7.74±0.24 (site II), 6.85±0.55 (site III), 7.55±0.49 (site IV) and the highest rainfall recorded in the month of August and the values were 556.28±1.01 (site I), 557.29±0.62 (site II), 556.70±1.14 (site III), 557.82±1.07 (site 4) (Table 4.19, Fig. 4.40).

On the other hand, during the second year (2020-2021), the minimum rainfall recorded for site I was in the month of October and its value is 0.63±0.11. Similarly for site II and site IV the value of minimum rainfall was recorded in the month of November and the values were 2.83±0.59 and 2.53±0.50 and in site III lowest rainfall readings recorded in the month of February (2.49±0.49). August was the month with the most imperative rainfall recorded from all of the four sites and the values are 581.56±1.23 (site I), 582.16±1.71 (site II), 582.15±1.82 (site III), and 582.25±1.82 (site IV) (Table 4.20, Fig.4.45).

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Table 4.15: Monthly Temperature (°C) recorded from different study sites during 2019-20

(All values are mean ± SE of three observations)

S. No.	Month/Site	Site I	Site II	Site III	Site IV
1.	APRIL	37.13±0.38	38.57±1.49	38.42±1.14	38.52±1.24
2.	MAY	39.30±0.80	40.14±0.19	40.41±1.68	40.65±1.29
3.	JUNE	42.93±0.11	43.35±0.50	43.42±1.17	42.89±1.66
4.	JULY	34.29±0.57	35.46±1.04	35.45±1.09	35.12±2.49
5.	AUGUST	33.33±0.63	33.46±0.86	33.22±1.13	34.40±1.23
6.	SEPTEMBER	31.31±0.71	32.33±0.81	32.28±1.19	32.28±1.32
7.	OCTOBER	29.35±1.08	30.29±1.01	30.49±0.91	30.11±1.14
8.	NOVEMBER	26.16±0.99	27.56±0.99	28.37±1.07	28.62±1.33
9.	DECEMBER	20.78±1.37	22.39±0.62	22.30±0.64	22.46±1.54
10.	JANUARY	19.96±1.05	21.29±1.43	21.55±1.20	21.66±1.08
11.	FEBRUARY	22.47±0.94	23.5±0.90	23.05±1.11	23.38±1.12
12.	MARCH	27.76±1.06	27.43±1.09	27.5±1.14	27.87±1.70

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Table 4.16: Monthly Temperature (°C) recorded from different study sites during 2020-21

(All values are mean ± SE of three observations)

S. No.	Month/Site	Site I	Site II	Site III	Site IV
1.	APRIL	35.28±1.28	36.83±1.81	36.50±1.30	36.67±0.88
2.	MAY	40.44±1.82	40.72±1.71	41.16±2.25	41.30±1.20
3.	JUNE	40.74±0.69	41.22±1.29	41.28±1.16	41.16±0.86
4.	JULY	36.37±0.97	37.36±0.97	37.72±1.60	37.44±0.90
5.	AUGUST	33.62±0.84	34.52±0.98	34.84±1.36	34.47±0.74
6.	SEPTEMBER	33.57±1.78	34.20±0.78	33.73±0.73	34.60±0.91
7.	OCTOBER	31.75±0.83	32.56±1.24	32.30±1.46	32.14±0.89
8.	NOVEMBER	26.76±1.22	27.72±1.31	27.24±0.79	27.38±0.99
9.	DECEMBER	24.45±1.91	24.87±1.45	24.61±1.50	24.54±0.87
10.	JANUARY	23.28±1.18	24.39±0.96	24.29±1.18	24.25±0.84
11.	FEBRUARY	27.39±1.45	26.54±2.03	26.51±1.34	26.51±1.23
12.	MARCH	34.51±0.99	33.35±1.08	33.35±1.35	34.44±1.22

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Table 4.17: Relative humidity (%) recorded from different study sites during 2019-20

(All values are mean ± SE of three observations)

S. No.	Month/site	Site I	Site II	Site III	Site IV
1.	APRIL	24.35±0.82	24.95±1.46	25.15±1.15	25.30±1.14
2.	MAY	16.69±0.63	17.02±0.13	17.39±0.74	17.65±1.17
3.	JUNE	23.60±0.92	24.28±1.28	25.31±1.20	24.43±1.47
4.	JULY	64.34±0.98	65.12±1.29	65.19±1.09	65.43±0.62
5.	AUGUST	76.65±1.51	77.34±0.88	77.08±1.18	77.37±1.38
6.	SEPTEMBER	78.26±1.52	78.73±1.60	79.11±1.14	79.38±0.74
7.	OCTOBER	66.49±1.33	67.51±1.34	67.54±1.20	66.25±1.65
8.	NOVEMBER	51.45±1.59	52.13±0.97	53.70±1.72	53.39±1.28
9.	DECEMBER	53.56±1.05	54.26±1.22	54.84±1.50	54.36±1.22
10.	JANUARY	67.05±0.96	68.40±1.32	68.36±1.40	68.30±1.07
11.	FEBRUARY	56.56±1.05	57.39±1.47	57.40±1.20	57.44±1.30
12.	MARCH	52.08±0.03	53.14±1.01	53.15±1.02	53.36±1.10

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Table 4.18: Relative humidity (%) recorded from different study sites during 2020-21

(All values are mean ± SE of three observations)

S. No.	Month/Site	Site I	Site II	Site III	Site IV
1.	APRIL	29.34±0.76	30.16±0.35	30.15±0.06	30.11±0.12
2.	MAY	26.50±1.22	27.14±0.30	27.12±0.03	27.04±0.06
3.	JUNE	37.29±0.82	38.08±0.22	38.09±0.14	38.04±1.04
4.	JULY	59.32±0.70	60.05±0.14	60.07±0.12	60.14±0.18
5.	AUGUST	78.19±1.04	79.10±0.21	79.13±0.22	78.78±1.68
6.	SEPTEMBER	68.18±1.12	69.17±0.14	69.12±0.24	69.09±0.08
7.	OCTOBER	48.56±1.18	49.12±0.15	49.15±0.39	49.06±0.08
8.	NOVEMBER	40.32±0.58	40.30±0.46	40.18±0.33	40.10±0.14
9.	DECEMBER	37.66±0.27	38.11±0.06	38.09±0.60	38.17±0.29
10.	JANUARY	44.35±0.57	45.07±0.06	45.26±0.90	45.45±1.08
11.	FEBRUARY	35.88±0.09	36.10±0.03	36.41±0.36	36.58±1.15
12.	MARCH	20.12±0.30	21.13±0.07	21.30±1.21	21.02±0.71

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Table 4.19: Rainfall (mm) recorded from different study sites during 2019-20

(All values are mean ± SE of three observations)

S. No.	Month/Site	Site I	Site II	Site III	Site IV
1.	APRIL	15.84±0.26	16.49±0.95	16.44±0.62	15.90±0.62
2.	MAY	14.78±0.61	15.07±1.05	15.12±0.08	14.88±0.63
3.	JUNE	35.69±0.31	36.40±0.64	36.07±0.85	35.79±0.67
4.	JULY	436.64±0.60	437.11±0.10	435.33±3.39	437.03±1.24
5.	AUGUST	556.28±1.01	557.29±0.62	556.70±1.14	557.82±1.07
6.	SEPTEMBER	317.62±0.89	318.37±0.06	317.87±0.50	317.89±1.78
7.	OCTOBER	22.64±0.46	23.67±0.21	22.75±0.64	22.51±1.07
8.	NOVEMBER	6.83±0.26	7.74±0.24	6.85±0.55	7.55±0.49
9.	DECEMBER	37.38±0.89	38.32±0.12	38.58±0.54	37.81±0.49
10.	JANUARY	147.56±0.44	148.63±0.96	148.17±0.62	148.02±1.59
11.	FEBRUARY	8.60±0.42	9.75±0.11	9.49±0.60	8.50±1.24
12.	MARCH	79.64±0.51	79.84±0.46	80.52±0.56	80.58±0.49

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Table 4.20: Rainfall (mm) recorded from different study sites during 2020-21

(All values are mean ± SE of three observations)

S. No.	Month/Site	Site I	Site II	Site III	Site IV
1.	APRIL	13.77±0.50	15.05±0.16	15.88±0.34	14.78±0.67
2.	MAY	15.97±0.67	17.05±0.73	17.50±0.61	16.79±0.67
3.	JUNE	54.56±0.60	54.88±0.58	55.52±0.64	54.80±0.49
4.	JULY	367.43±1.23	368.80±1.65	369.47±0.55	368.52±1.24
5.	AUGUST	581.56±1.25	582.16±1.71	582.15±1.82	582.25±1.82
6.	SEPTEMBER	101.56±1.24	103.85±1.18	102.19±1.82	102.30±1.65
7.	OCTOBER	0.63±0.11	0.00	0.00	0.00
8.	NOVEMBER	1.46±0.02	2.83±0.59	2.78±1.24	2.53±0.50
9.	DECEMBER	14.03±0.25	15.97±0.64	14.79±0.49	14.90±0.50
10.	JANUARY	8.66±0.48	9.64±0.47	9.82±1.07	9.52±0.49
11.	FEBRUARY	1.62±0.58	2.96±0.96	2.49±0.49	2.55±0.49
12.	MARCH	10.43±0.62	11.02±0.13	10.83±0.64	10.53±1.14

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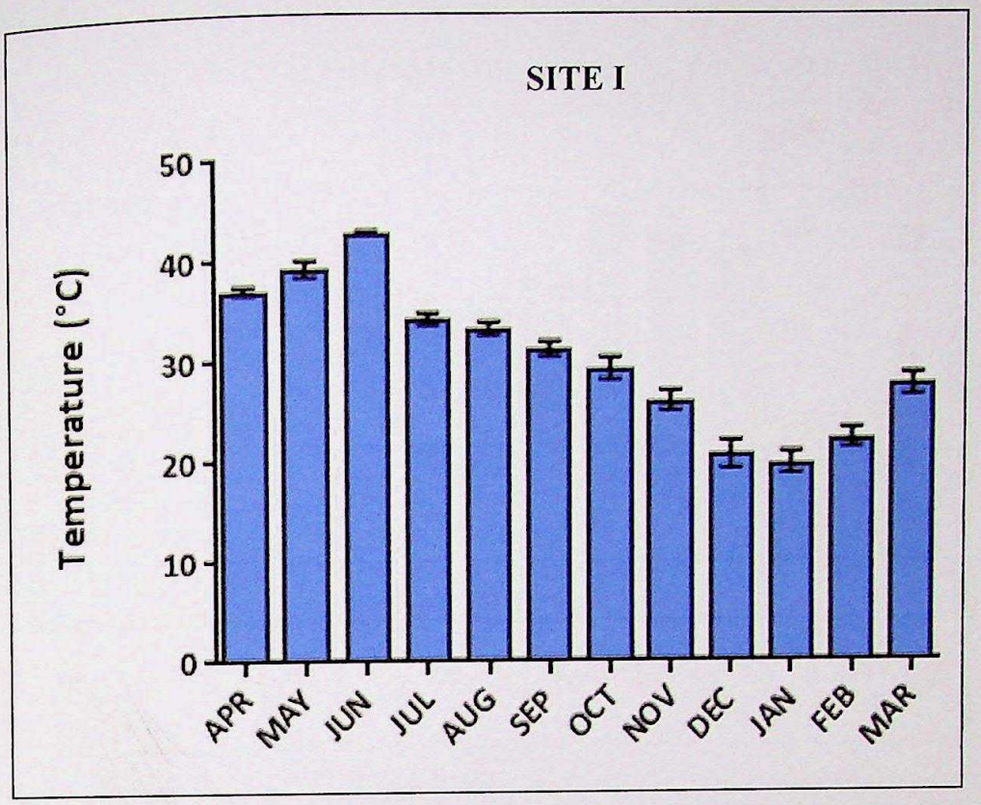

Fig 4.16: Monthly temperature recorded from site I during 2019-20

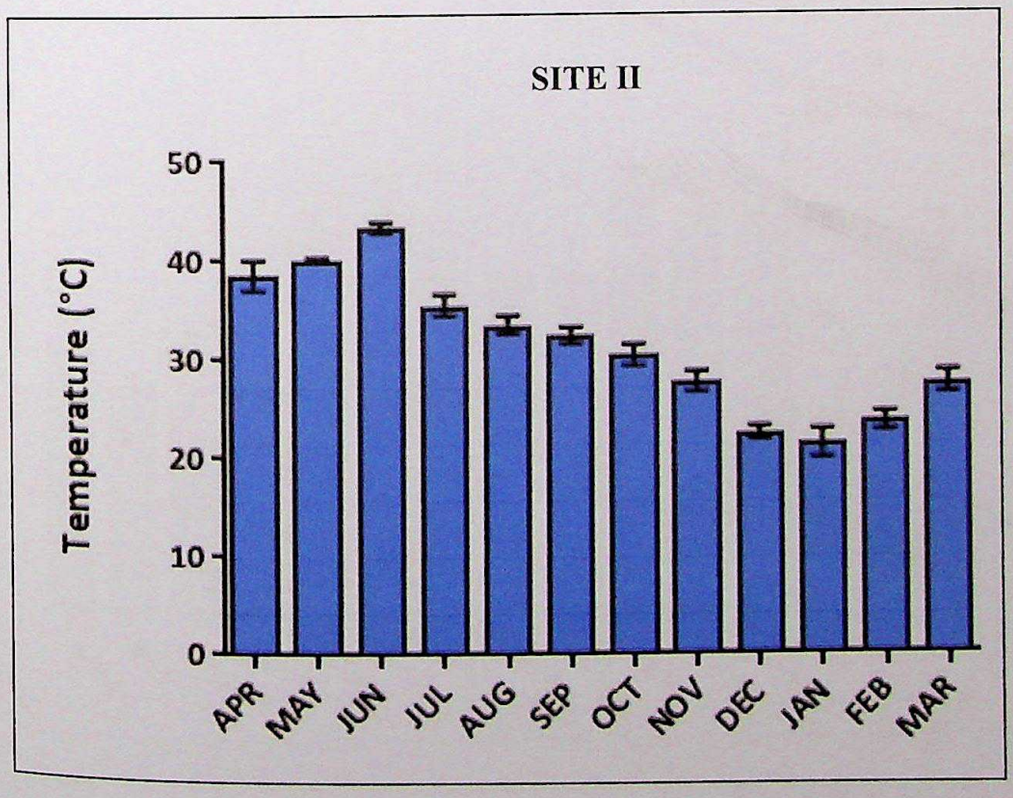

Fig 4.17: Monthly temperature recorded from site II during 2019-20

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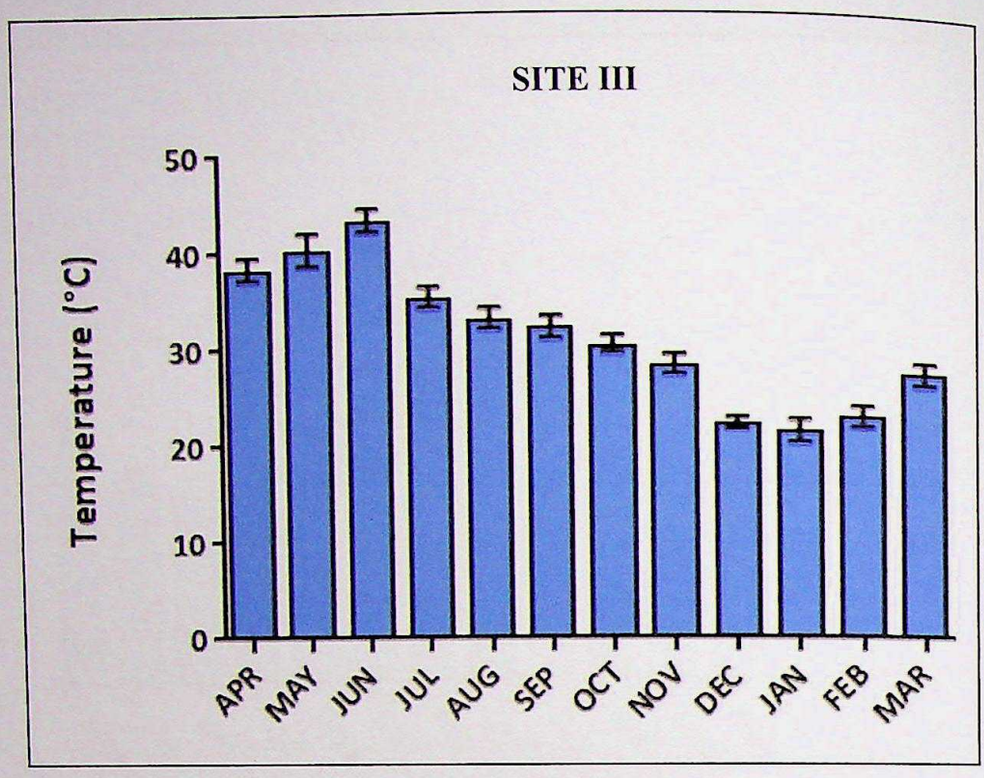

Fig 4.18: Monthly temperature recorded from site III during 2019-20

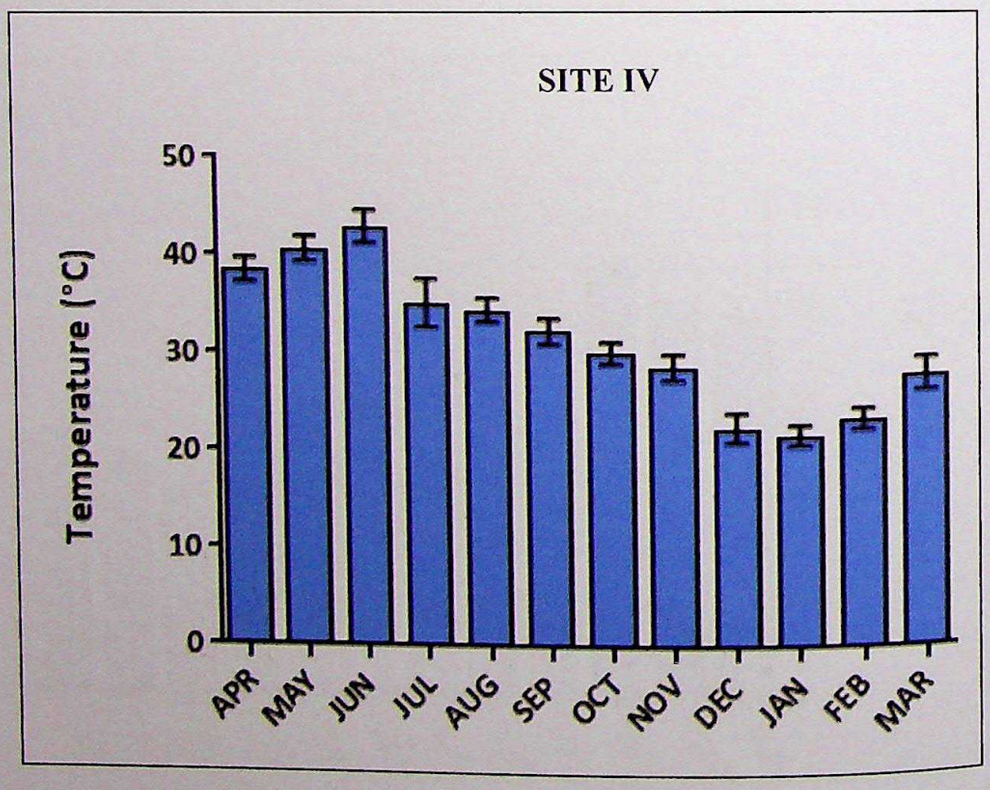

Fig 4.19: Monthly temperature recorded from site IV during 2019-20

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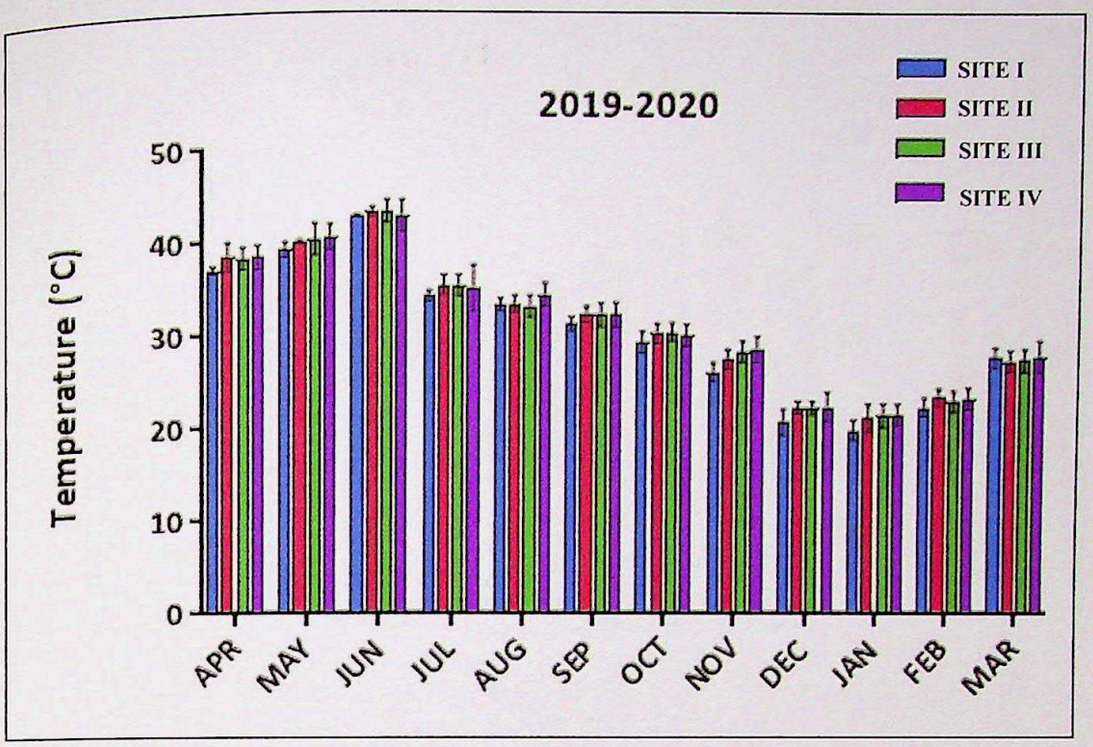

Fig 4.20: Monthly temperature recorded from all study sites during 2019-20

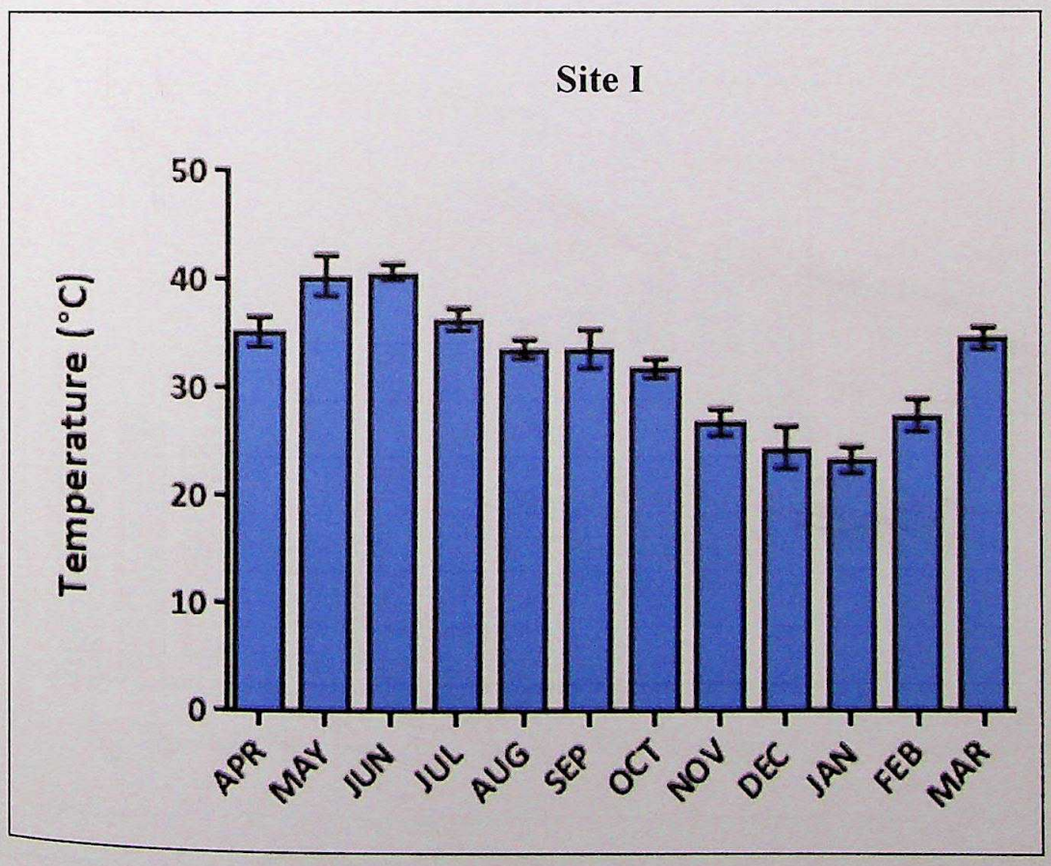

Fig 4.21: Monthly temperature recorded from sites I during 2020-21

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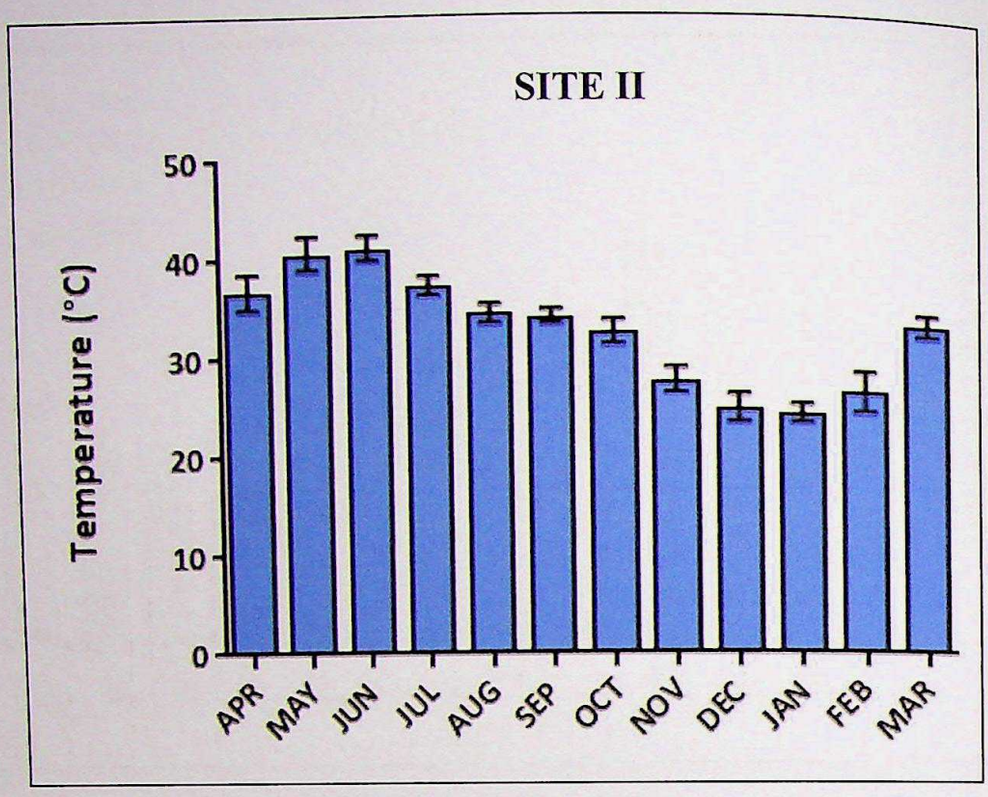

Fig 4.22: Monthly temperature recorded from sites II during 2020-21

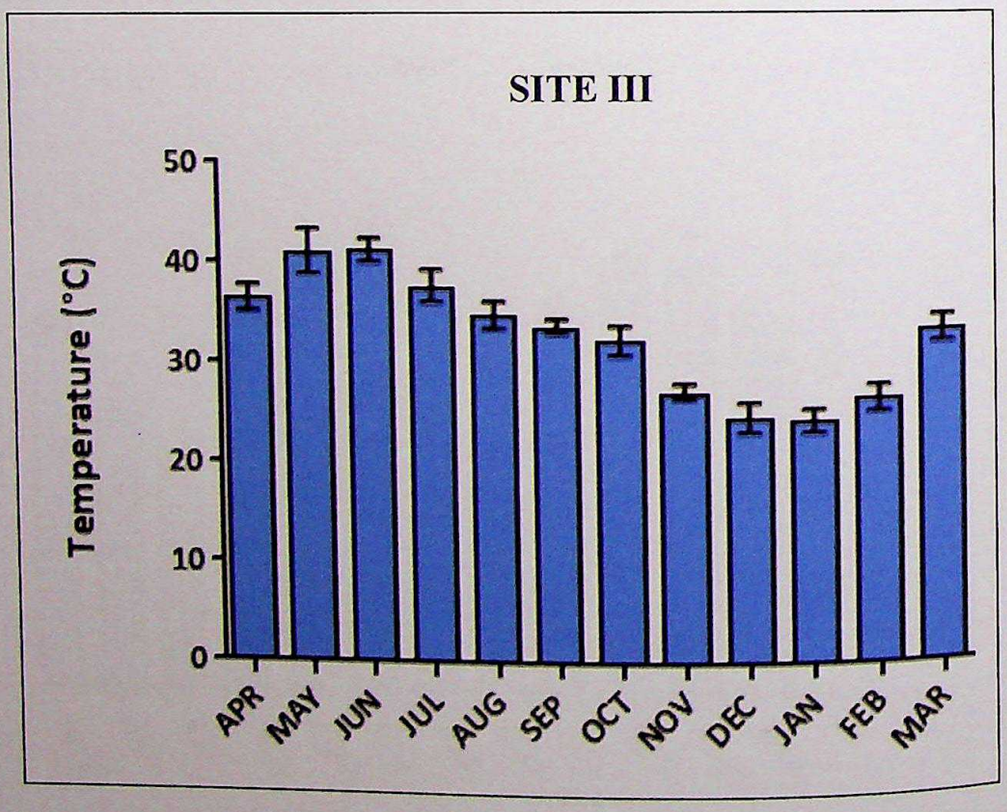

Fig 4.23: Monthly temperature recorded from sites III during 2020-21

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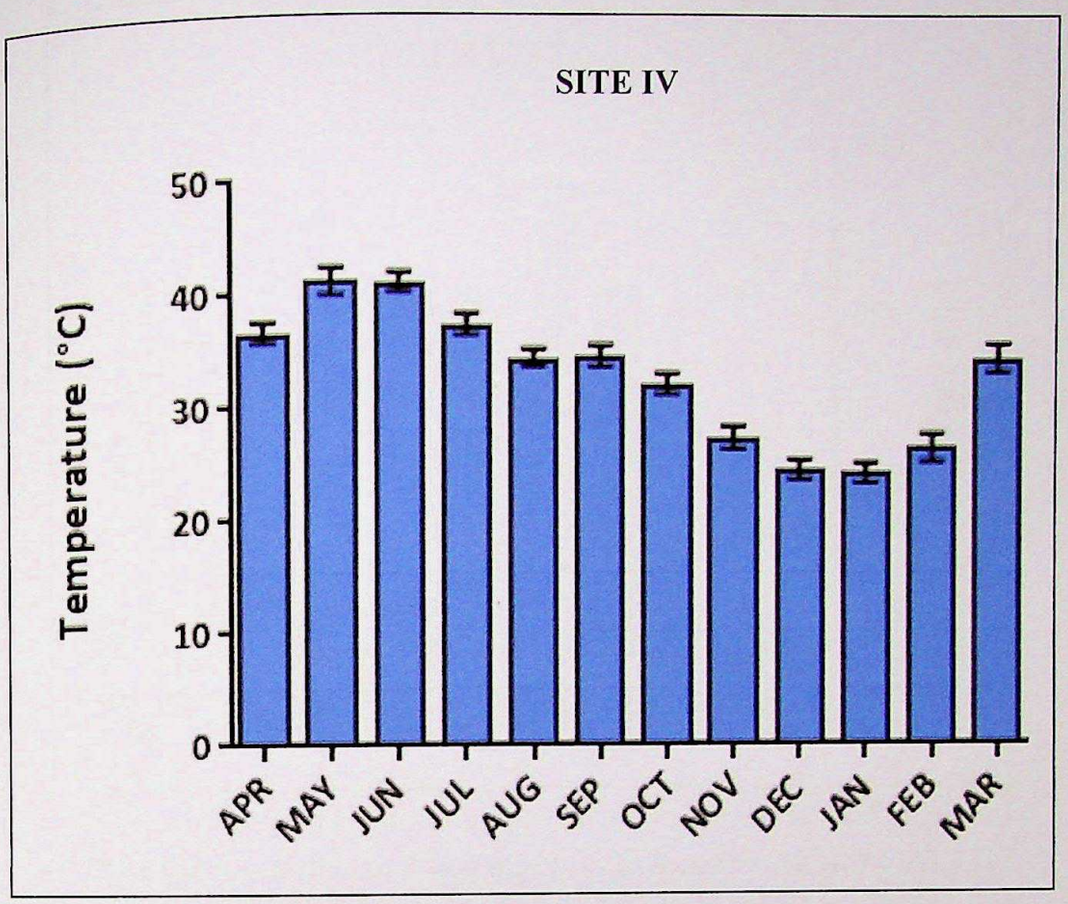

Fig 4.24: Monthly temperature recorded from sites IV during 2020-21

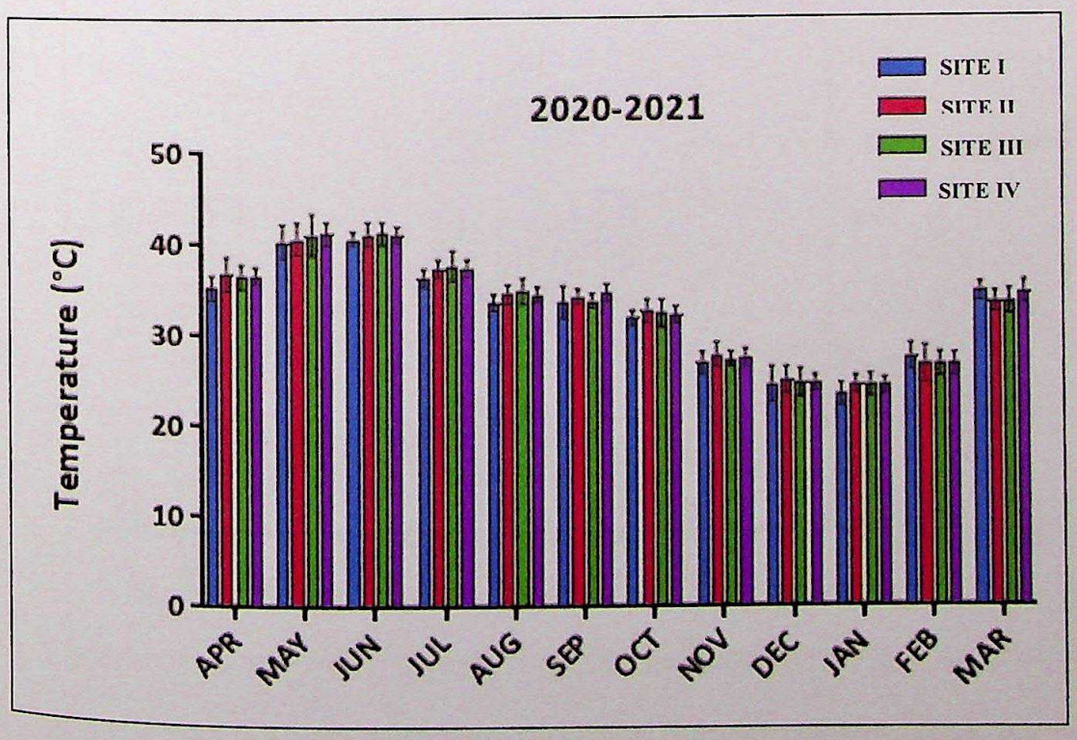

Fig 4.25: Monthly temperature recorded from all study sites during 2020-21

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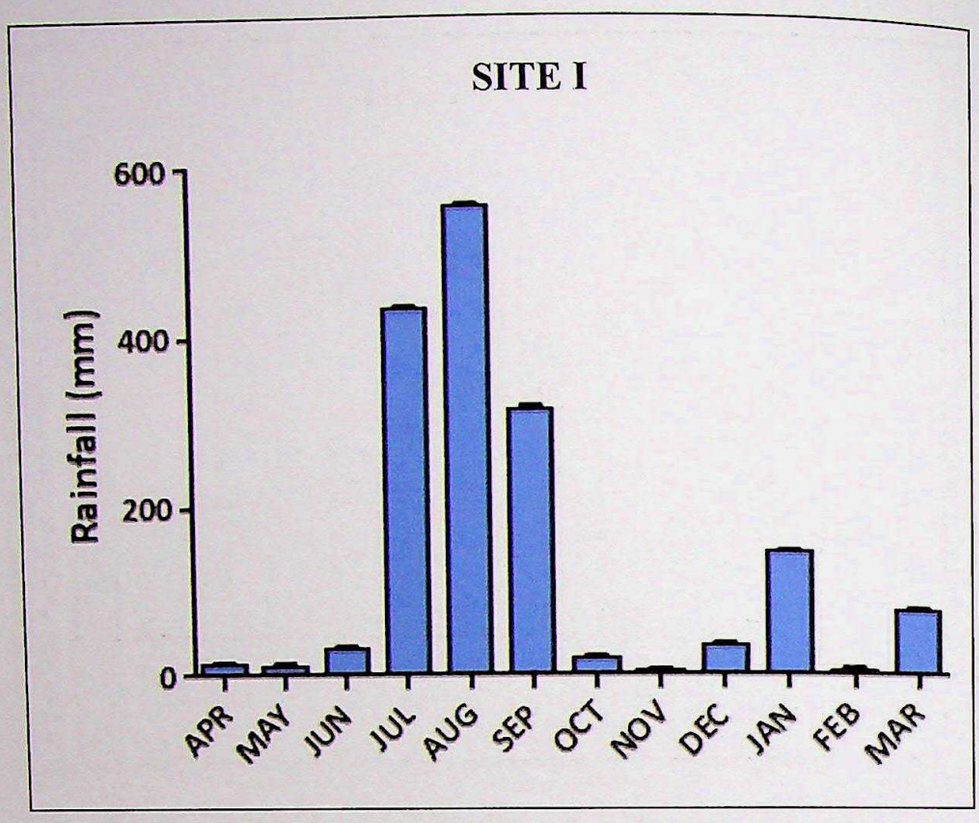

Fig 4.26: Monthly rainfall (mm) recorded from site I during 2019-20

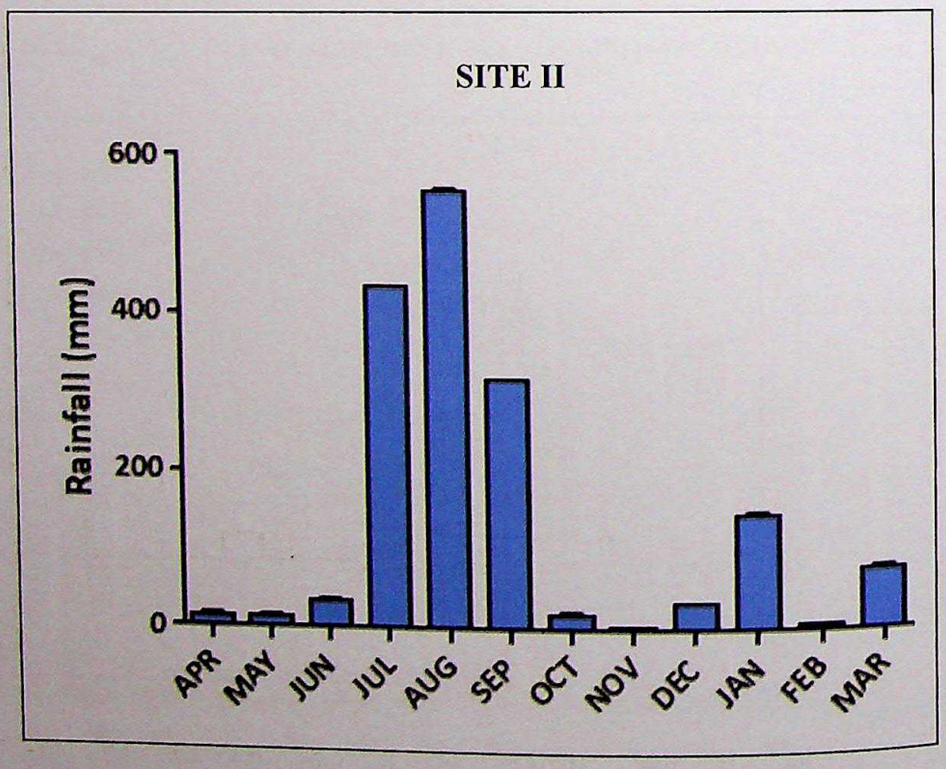

Fig 4.27: Monthly rainfall (mm) recorded from site II during 2019-20

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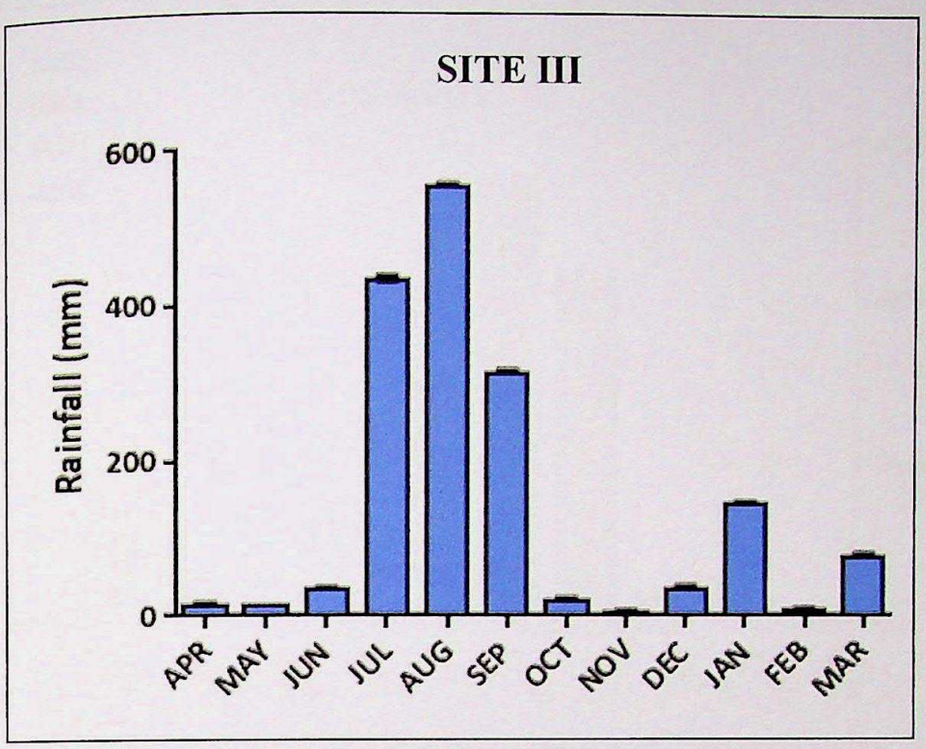

Fig 4.28: Monthly rainfall (mm) recorded from site III during 2019-20

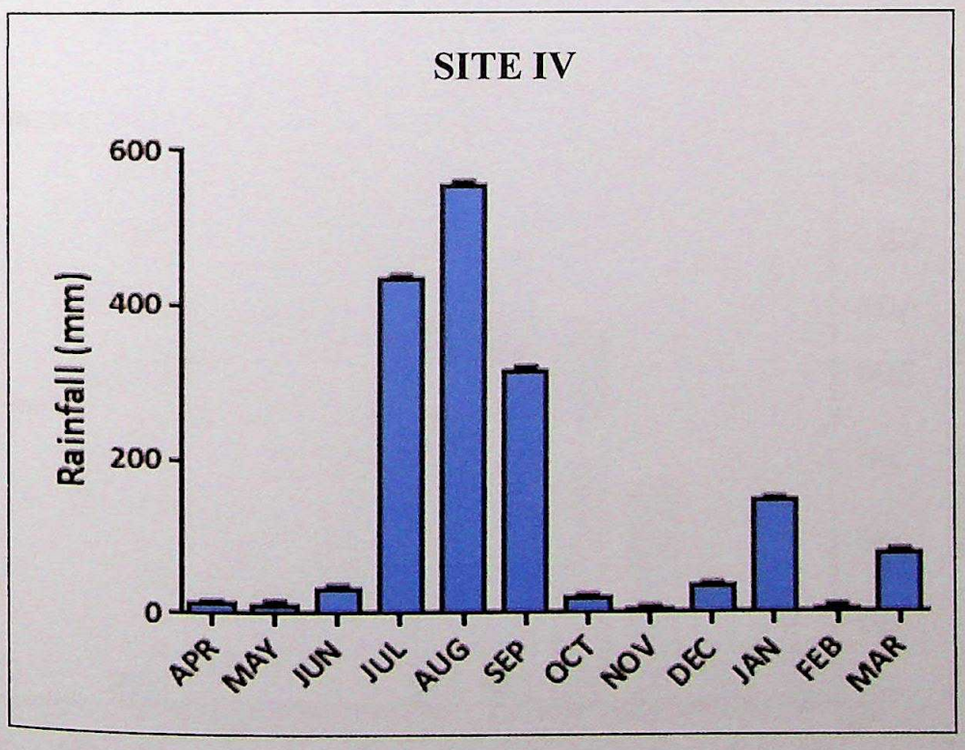

Fig 4.29: Monthly rainfall (mm) recorded from site IV during 2019-20

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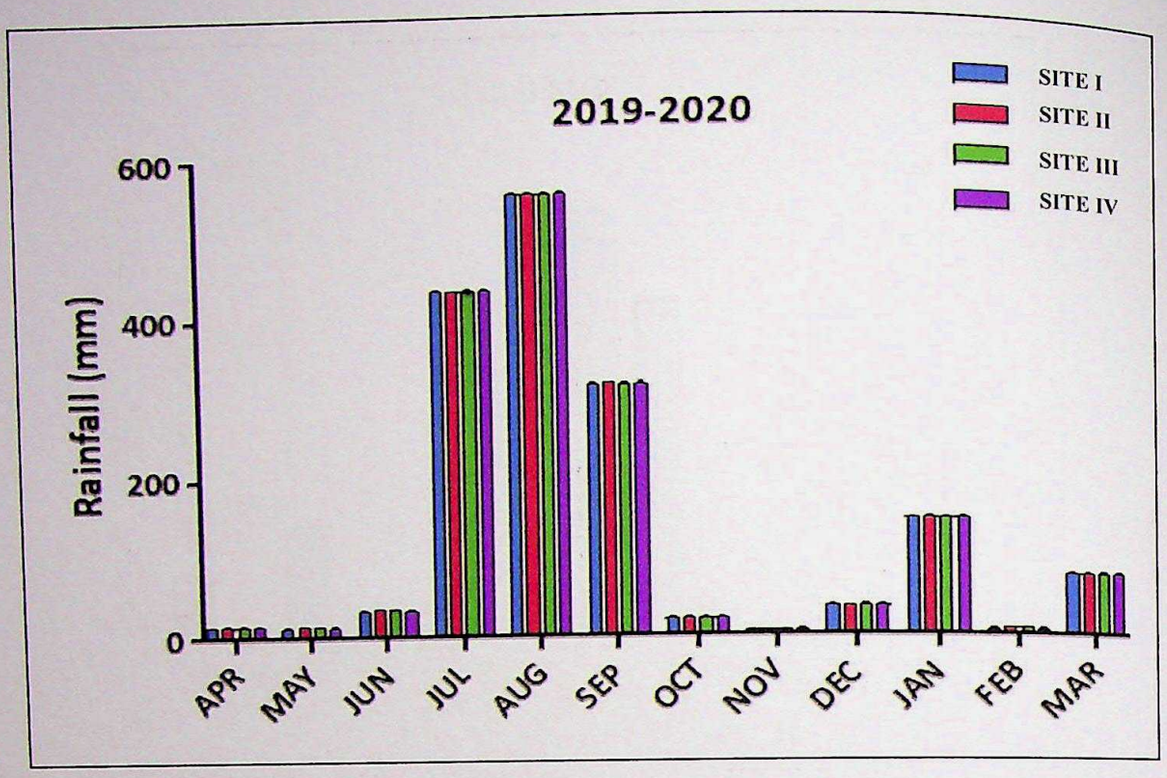

Fig 4.30: Comparative monthly rainfall (mm) recorded from all sites during 2019-20

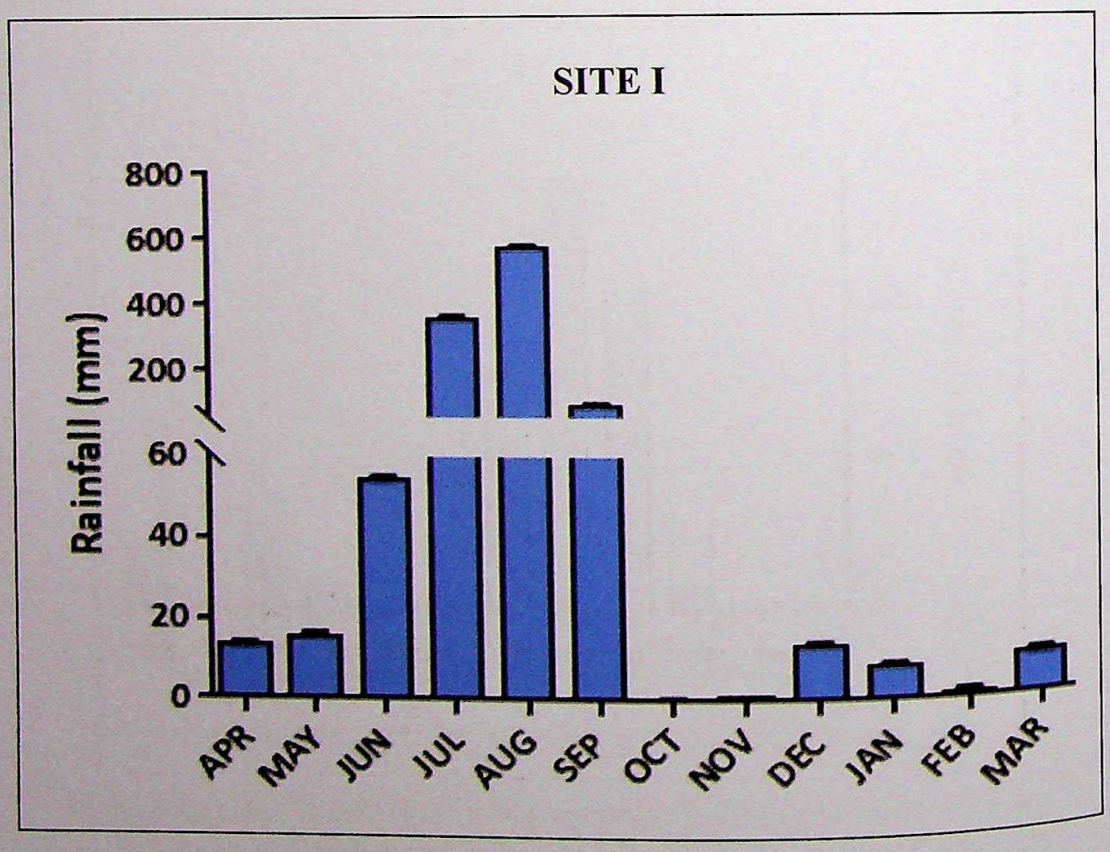

Fig 4.31: Monthly rainfall (mm) recorded from site I during 2020-21

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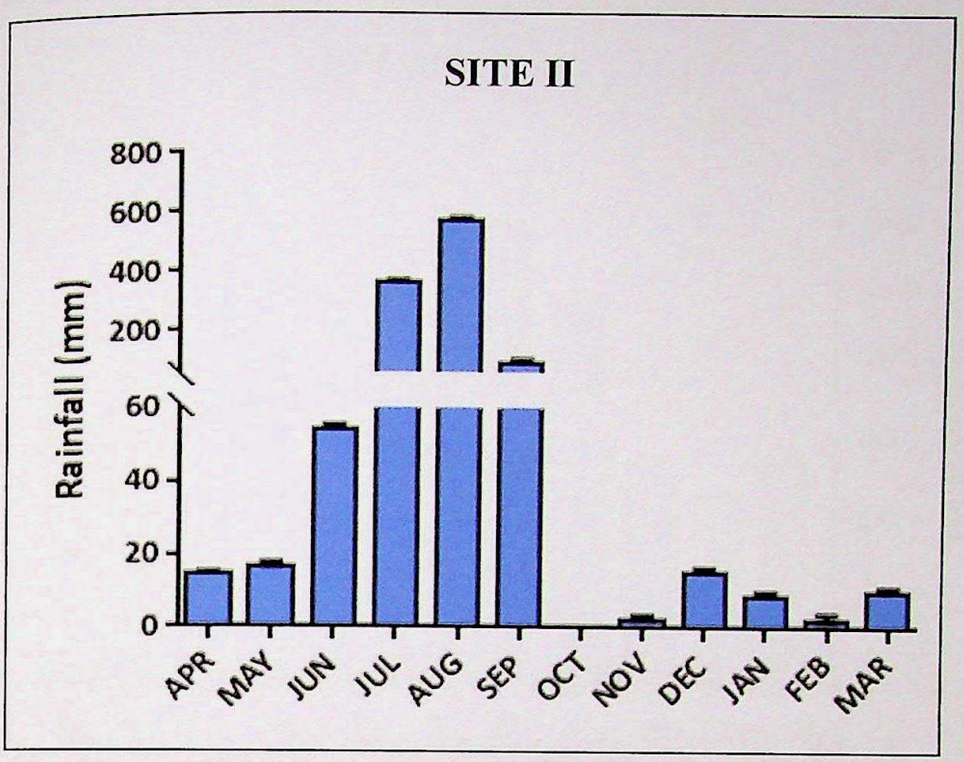

Fig 4.32: Monthly rainfall (mm) recorded from site II during 2020-21

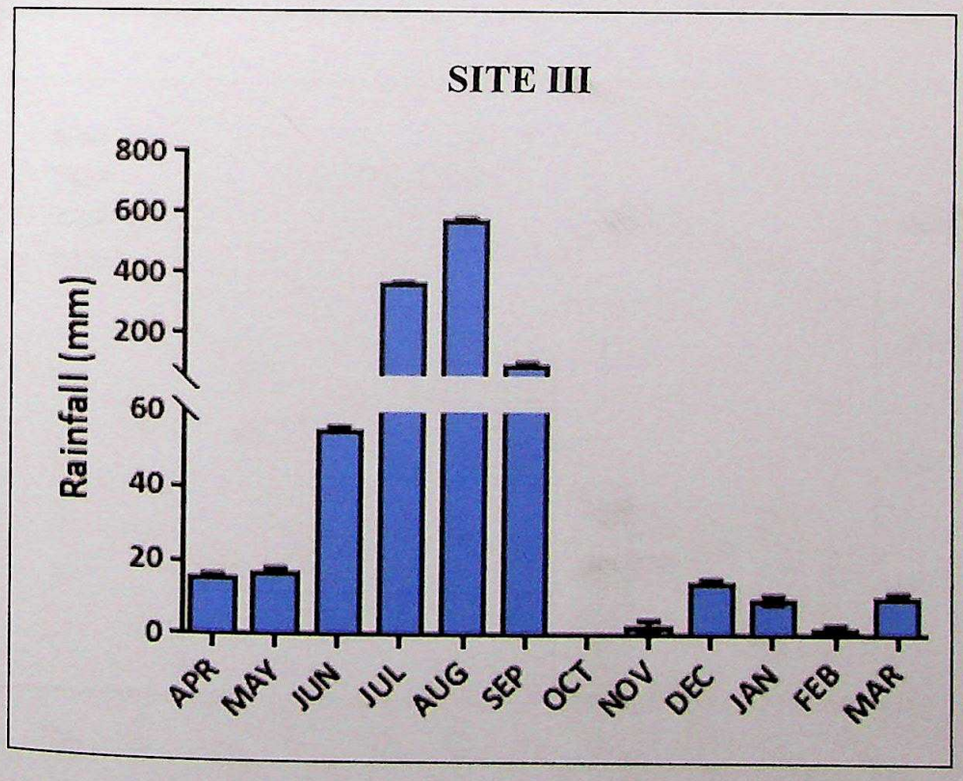

Fig 4.33: Monthly rainfall (mm) recorded from site III during 2020-21

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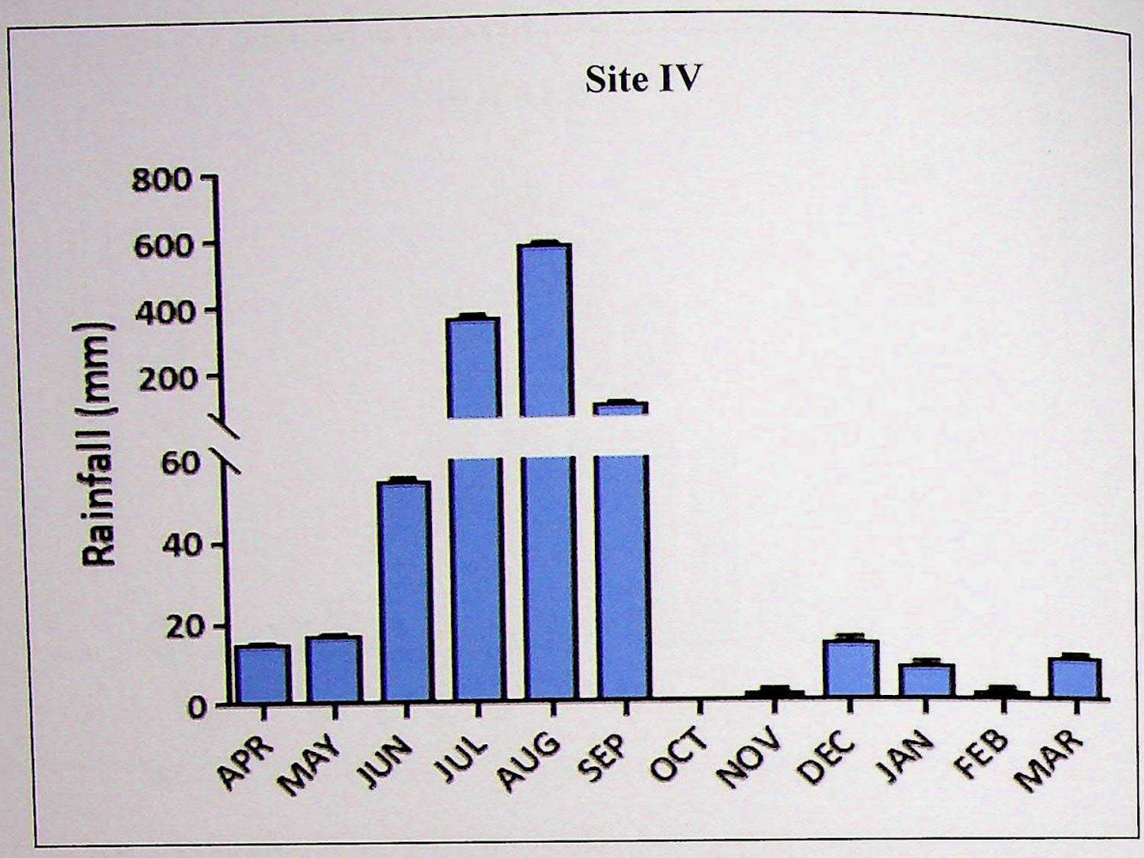

Fig 4.34: Monthly rainfall (mm) recorded from site IV during 2020-21

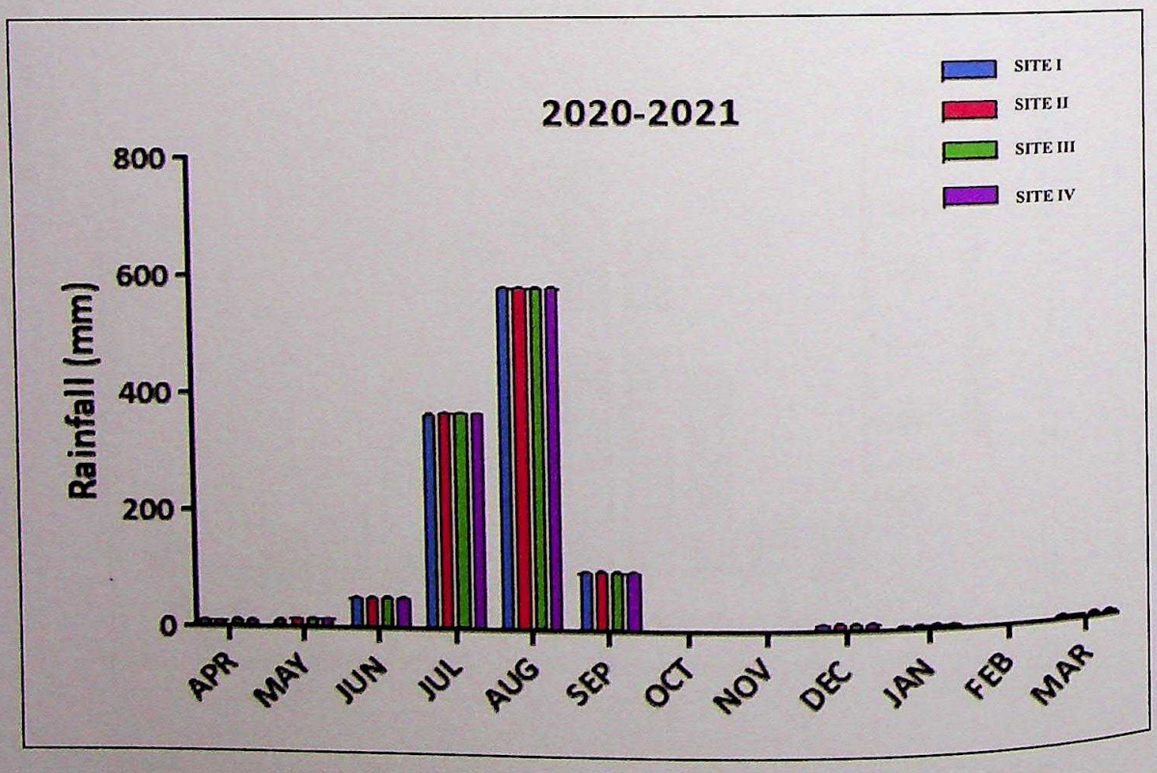

Fig 4.35: Comparative monthly rainfall (mm) recorded from all sites during 2020-21

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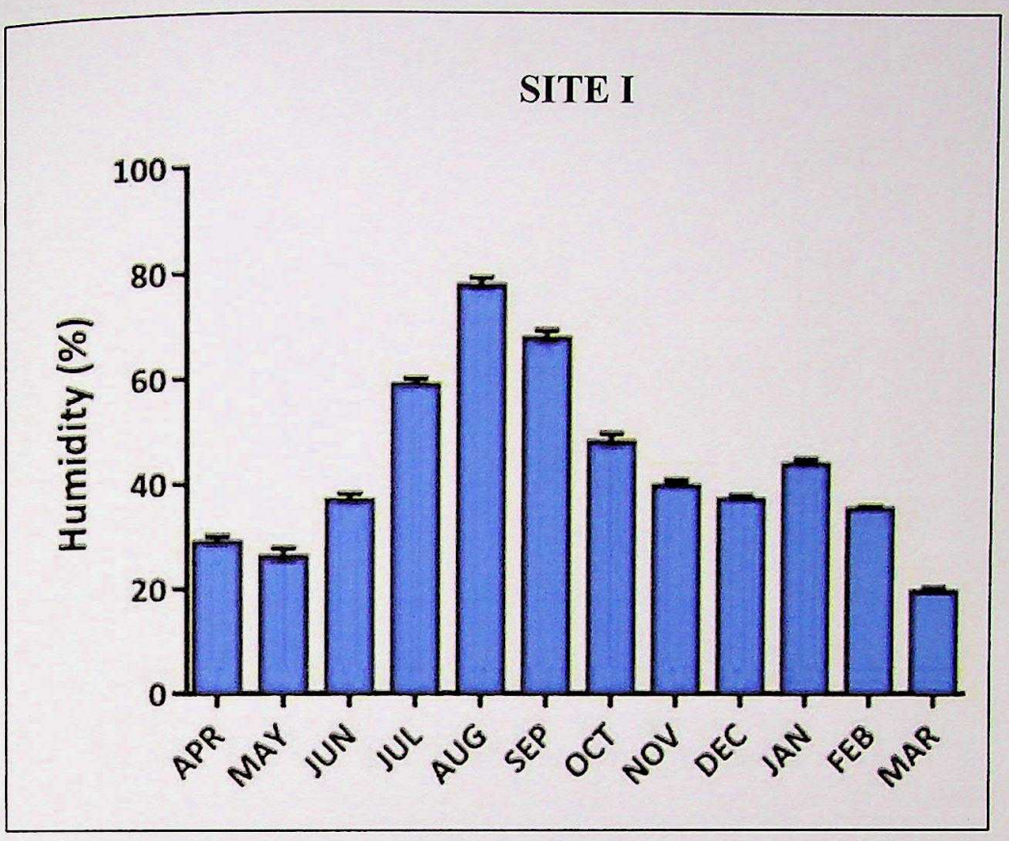

Fig 4.36: Relative humidity (%) recorded from site I during 2019-20

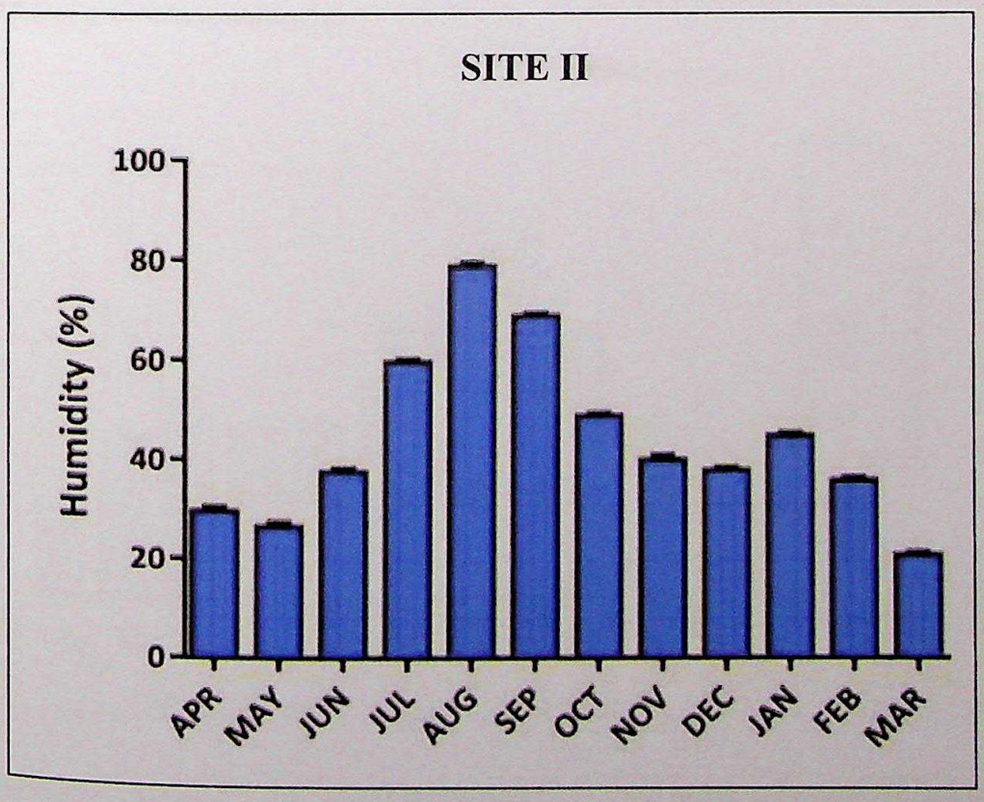

Fig 4.37: Relative humidity (%) recorded from site II during 2019-20

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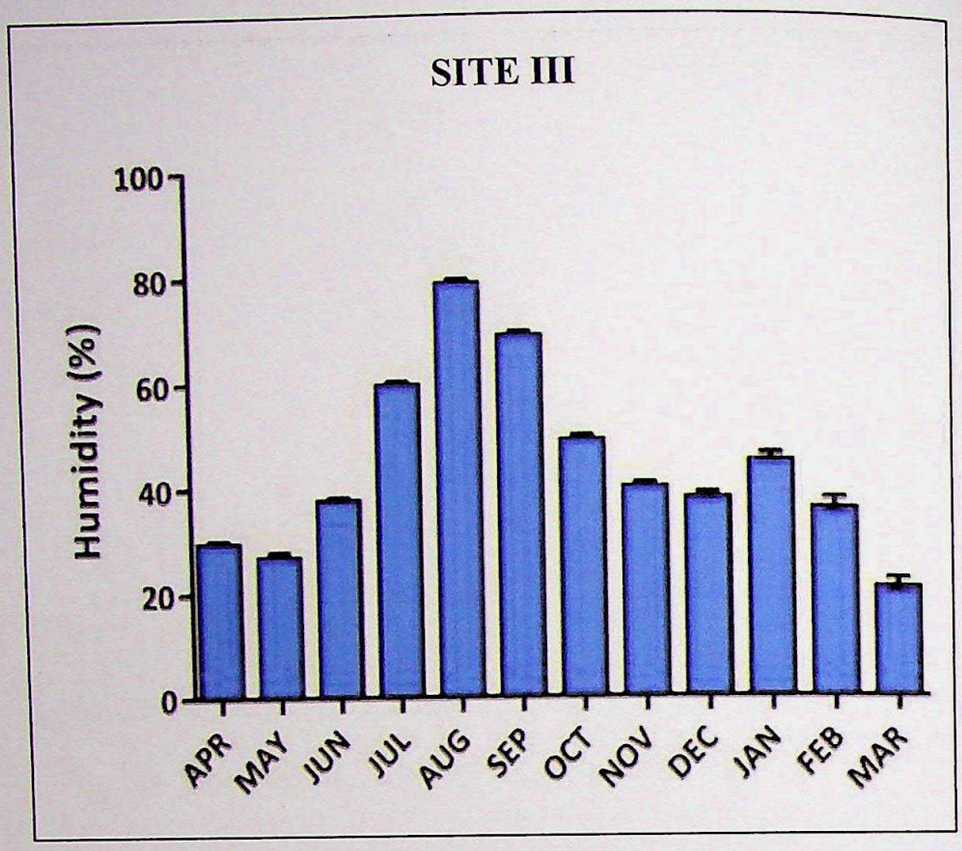

Fig 4.38: Relative humidity (%) recorded from site III during 2019-20

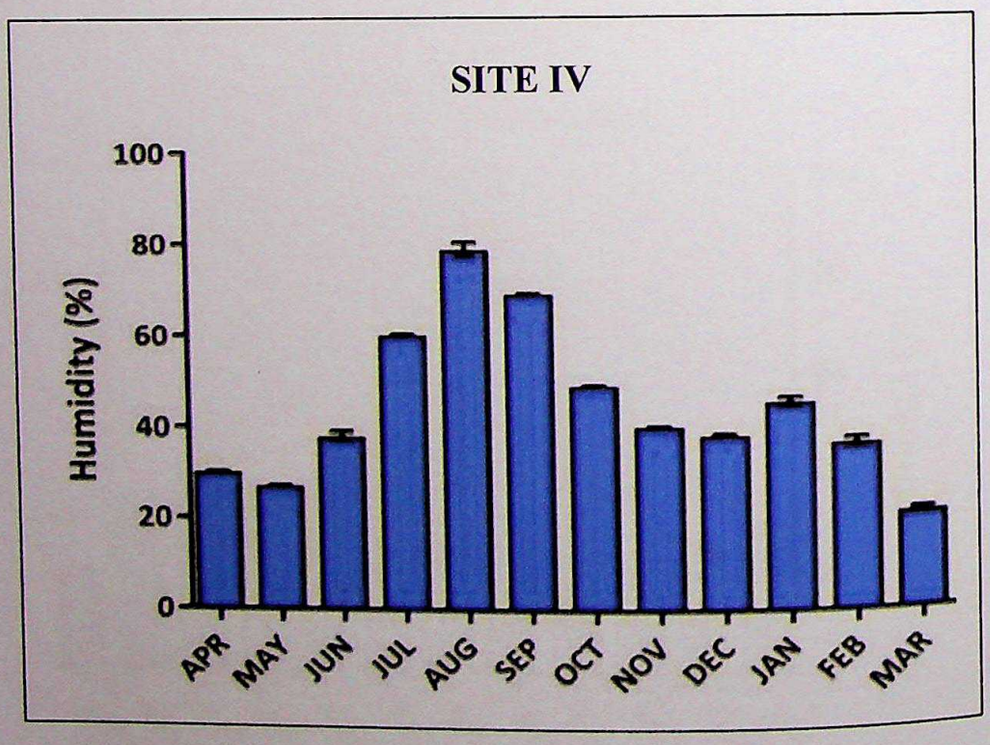

Fig 4.39: Relative humidity (%) recorded from site IV during 2019-20

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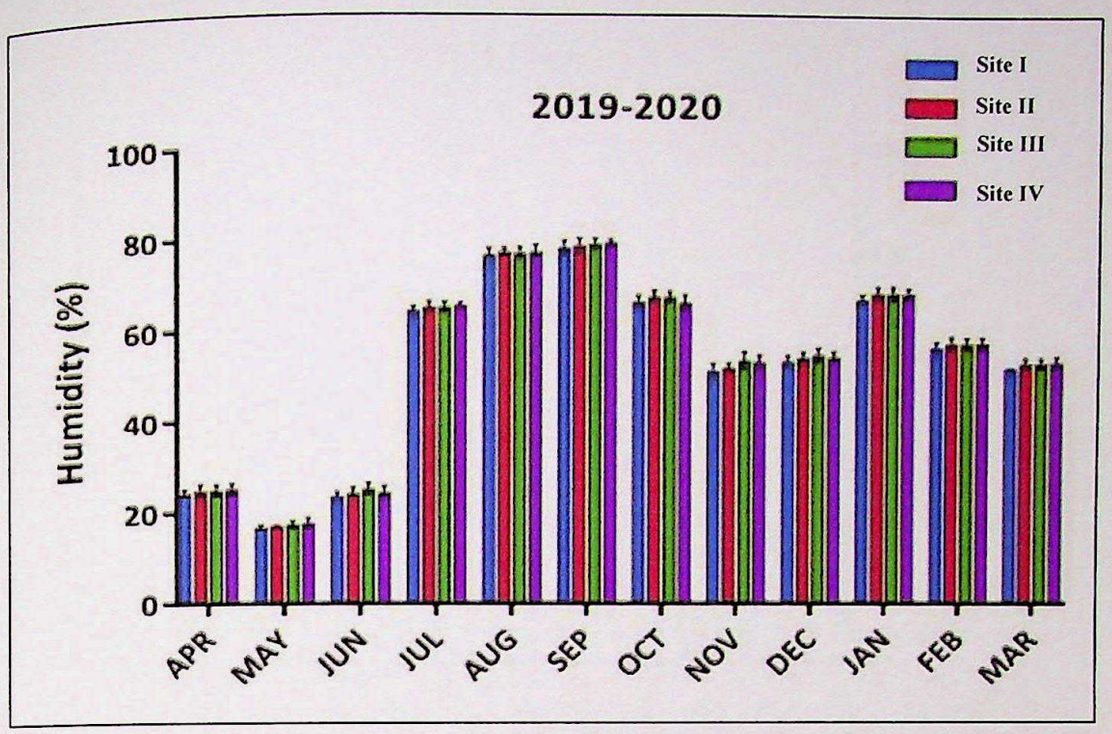

Fig 4.40: Comparative relative humidity (%) recorded from all study sites during 2019-20

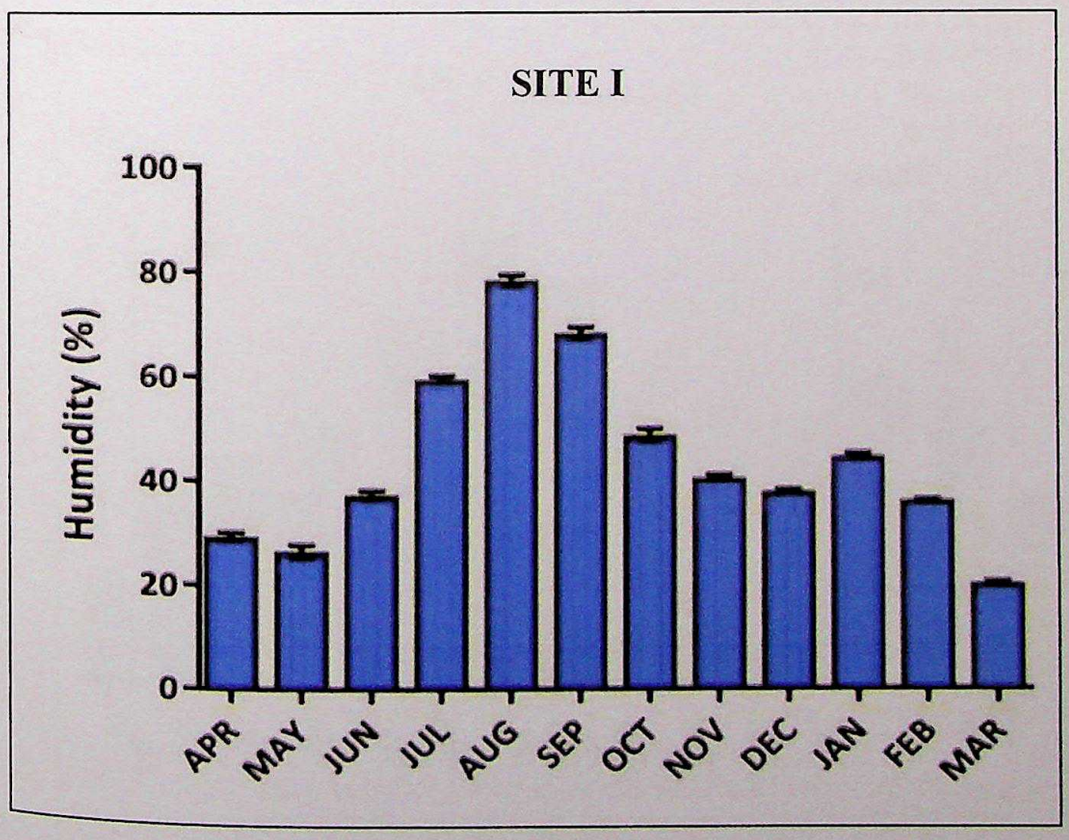

Fig 4.41: Relative humidity (%) recorded from site I during 2020-21

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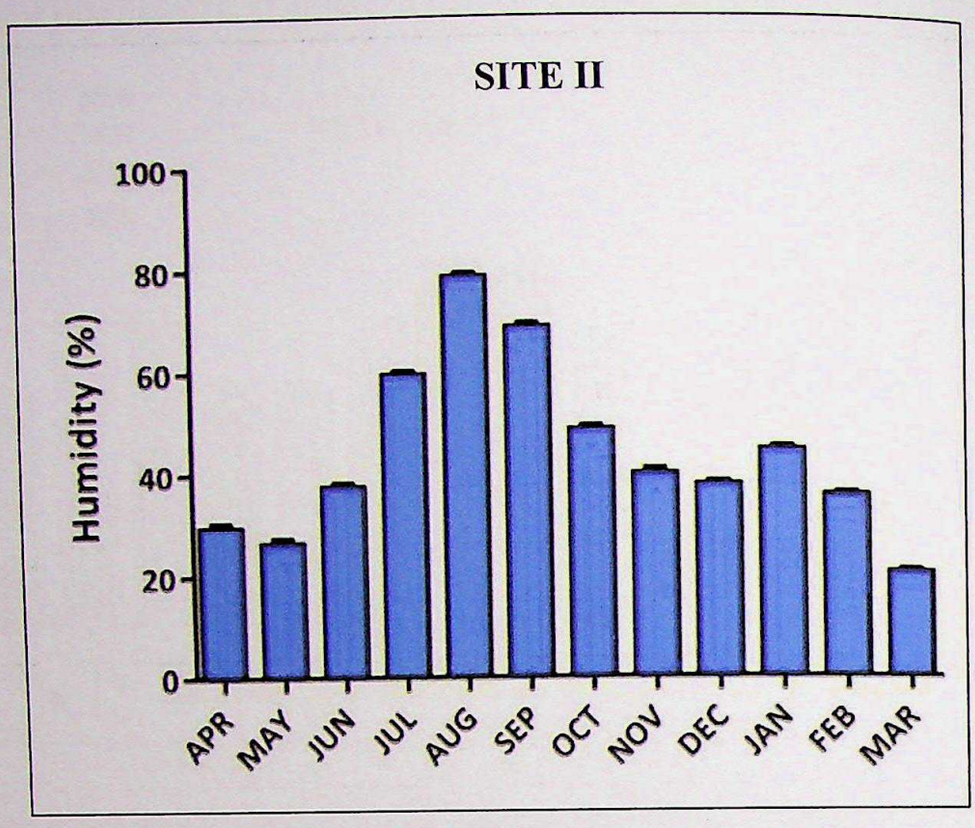

Fig 4.42: Relative humidity (%) recorded from site II during 2020-21

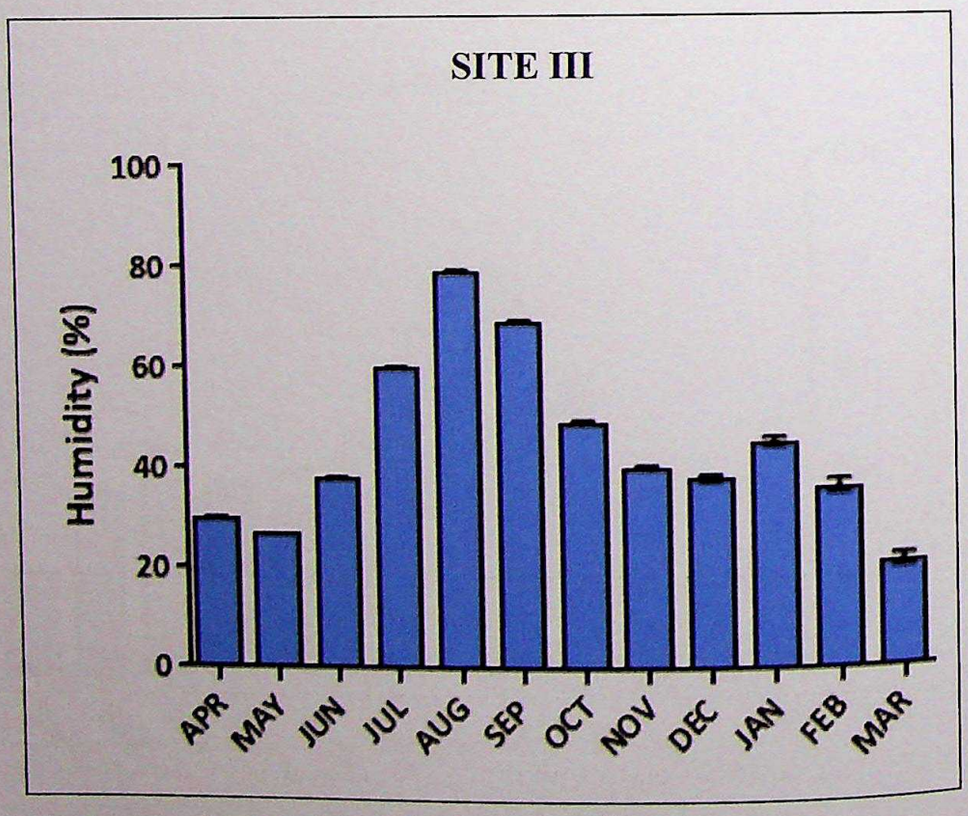

Fig 4.43: Relative humidity (%) recorded from site III during 2020-21

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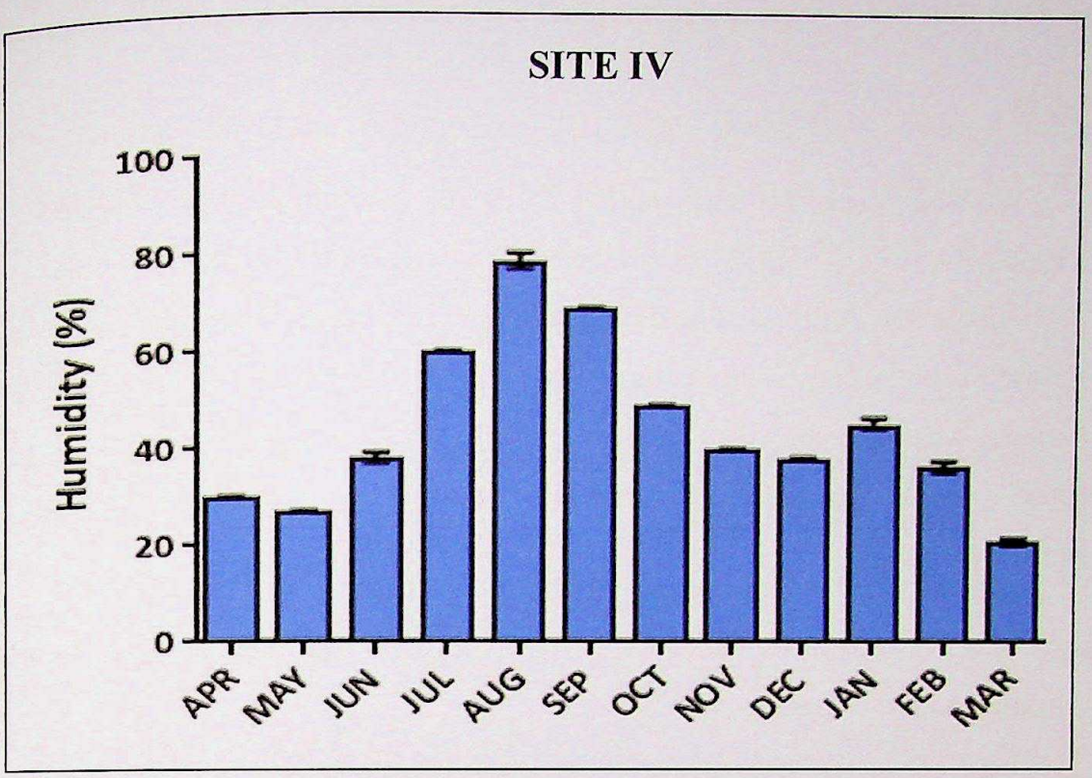

Fig 4.44: Relative humidity (%) recorded from site IV during 2020-21

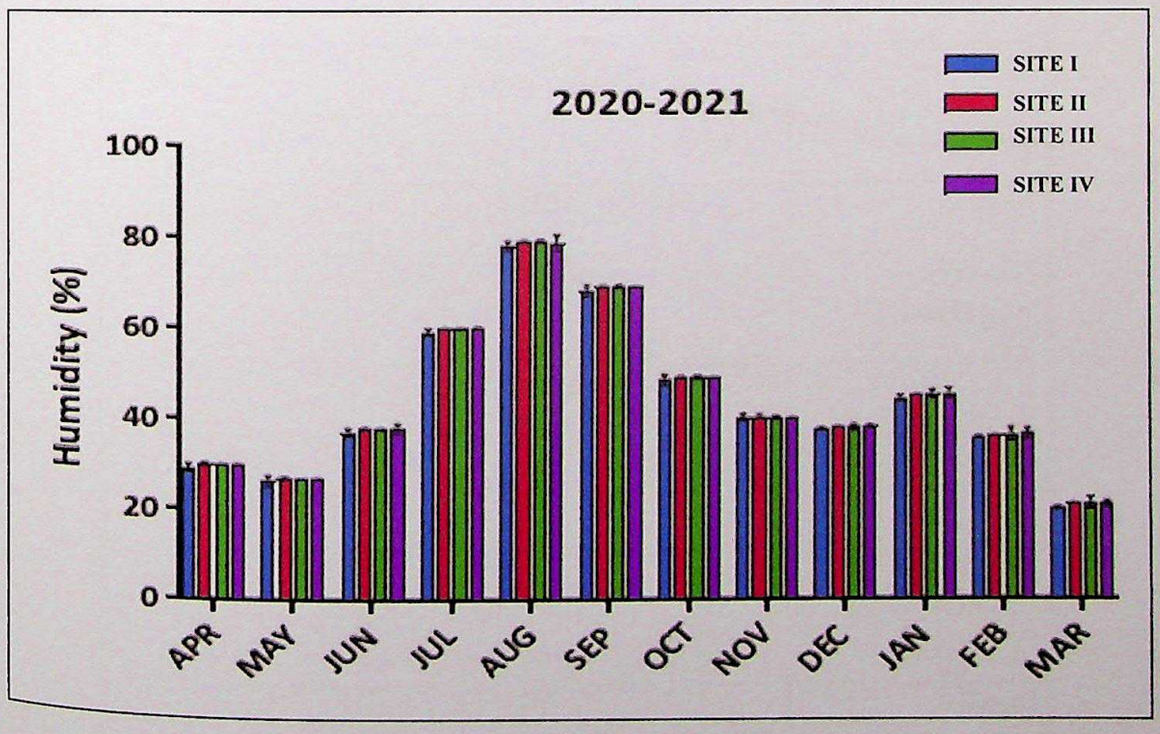

Fig 4.45: Comparative relative humidity (%) recorded from all study sites during 2020-21

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4.4.1 Correlation between meteorological parameters and butterfly abundance

SITE I

During the first year of the study period (2019-20), a strong positive correlation was observed between the butterfly abundance and temperature (r=0.867; p=>0.05) and a slight positive correlation was observed between the butterfly abundance and rainfall (r=0.064) (Table 4.21). Likewise, during the second year (2020-21), a strong positive correlation was observed between the butterfly abundance and temperature (r=0.935; p=>0.005), and slight positive correlation between the butterfly abundance and rainfall (r= 0.314).

Table 4.21: Correlation between meteorological parameters and butterfly abundance at site I during 2019-21

2019-20				
	Temp	*Rh%*	*Rainfall*	*Butterfly Abundance*
Temp	1			
Rh%	-0.556	1		
Rainfall	0.134	0.625	1	
Butterfly Abundance	0.867*	-0.594	0.064	1
2020-21				
	Temp	*Rh%*	*Rainfall*	*Butterfly Abundance*
Temp	1			
Rh%	-0.048	1		
Rainfall	0.237	0.773	1	
Butterfly Abundance	0.935**	-0.074	0.314	1

p

** >0.005, *>0.05

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SITE II

During the first year of the study period (2019-20), a strong positive correlation was observed between the butterfly abundance and temperature (r=0.8818; p= >0.05) (Table 4.22). Similarly, during the study year of the study period (2020–21), a strong positive correlation between the butterfly abundance and temperature was observed (r=0.886; p=>0.05).

Table 4.22: Correlation between meteorological parameters and butterfly abundance at site II during 2019-21

2019- 20				
	Temp	*Rh%*	*Rainfall*	*Butterfly Abundance*
Temp	1			
Rh%	-0.576	1		
Rainfall	0.116	0.622	1	
Butterfly Abundance	0.881*	-0.769	-0.098	1
2021-22				
	Temp	*Rh%*	*Rainfall*	*Butterfly Abundance*
Temp	1			
Rh%	0.019	1		
Rainfall	0.269	0.777	1	
Butterfly Abundance	0.886*	-0.068	0.253	1

p

*>0.05

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SITE III

During the first year of the study period (2019-20), a strong positive correlation was observed between the butterfly abundance and temperature (r=0.8798; p= >0.05) (Table 4.23). Similarly during the second year of the study period (2020–201), a strong positive correlation was observed between the butterfly abundance and temperature (r=0.89201; p=>0.05).

Table 4.23: Correlation between meteorological parameters and butterfly abundance at site III during 2019-21

2019-20				
	Temp	*Rh%*	*Rainfall*	*Butterfly Abundance*
Temp	1			
Rh%	-0.583	1		
Rainfall	0.102	0.617	1	
Butterfly Abundance	0.879*	-0.818	-0.179	1
2020-21				
	Temp	*Rh%*	*Rainfall*	*Butterfly Abundance*
Temp	1			
Rh%	0.020	1		
Rainfall	0.292	0.776	1	
Butterfly Abundance	0.892*	-0.079	0.252	1

p

*>0.05

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SITE IV

During the first year of the study period (2019-20), a strong positive correlation was observed between the butterfly abundance and temperature (r=0.869; p=>0.05) (Table 4.24). Likewise during the second year of the study period (2020-21), a strong positive correlation was observed between the butterfly abundance and temperature (0.878; p=>0.05).

Table 4.24: Correlation between meteorological parameters and butterfly abundance at site IV during 2019-21

2019-20				
	Temp	*Rh%*	*Rainfall*	*Butterfly Abundance*
Temp	1			
Rh%	-0.574	1		
Rainfall	0.127	0.627	1	
Butterfly Abundance	0.869*	-0.822	-0.182	1
2020-21				
	Temp	*Rh%*	*Rainfall*	*Butterfly Abundance*
Temp	1			
Rh%	-0.006	1		
Rainfall	0.260	0.774	1	
Butterfly Abundance	0.878*	-0.120	0.219	1

p

*>0.05

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Overall in all four sites there has been a significant correlation between the temperature and butterfly abundance which indicates that the temperature plays a crucial role in determining the butterfly abundance.

4.4.2 SOIL TYPE:

Table 4.25: Values of selected soil parameters of different sites during (2019-20)

Parameters	Unit	Site I	Site II	Site III	Site IV
pH	-	8.18	7.84	7.69	7.34
Organic Carbon	%	4.72	2.86	1.45	1.18
Moisture content	%	19.6	11.89	8.67	7.48
Clay	%	67	59	53	53
Silt	%	26	35	36	28
Sand	%	7	6	11	17
Bulk Density	g/cc	1.48	1.21	1026	1.17
Soil type	-	Sandy loamy	Sandy loamy	Sandy loamy	Sandy loamy

Table 4.26: Values of selected soil parameters of different sites during (2020-21)

Parameters	Unit	Site I	Site II	Site III	Site IV
pH	-	8.23	7.96	7.82	7.48
Organic Carbon	%	4.89	3.12	1.68	1.23
Moisture content	%	22.68	13.61	8.96	7.84
Clay	%	68	58	52	51
Silt	%	27	33	38	31
Sand	%	5	9	10	18
Bulk Density	g/cc	1.64	1.34	1.18	1.23
Soil type	-	Sandy loam	Loamy sand	Sandy loam	Sandy loam

Site I showed the presence of sandy loam soil, site II soil was loamy sand, site III have sandy loam while site IV soil was also sandy loam in texture.

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During the study period 2019-20 it was found that the pH of soil was found to be 8.18, 7.84,7.69 and 7.34 while organic matter was 4.72, 2.86, 1.45 and 1.18% for site I, site II, site III, site IV respectively. Likewise, site I, II, III and IV had moisture content of 19.6, 11.89, 8.67 and 7.48% On the other hand Site I had 67, 23 and 3% of clay, sand and silt, site II had 59, 35 and 6% clay, sand and silt, site III showed clay, sand silt of 53, 36, 11% while site IV soil was having 53, 28, 17 % of clay, sand and silt. The bulk density of soil was recorded as 1.48, 1.21, 1.26 and 1.17 g/cc for site I, site II, site III and site IV respectively.

Similarly, from 2020-21 soil pH was 8.23, 7.96, 7.82, and 7.48 from site I, II, III and IV respectively. However, the soil organic matter and moisture content were 4.89, 3.12, 1.68, 1.23% and 22.68, 13.61, 8.96 and 7.84% for site I, II, III and IV respectively. The clay, silt and sand composition of soil was 68, 27,5% for site I, 58, 33, 9% for site II, 52, 38, 10 % for site III and 51, 31,18 % for site IV. Wherein the bulk density was 1.64, 1.34, 1.18 and 1.23 g/cc respectively.

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CHAPTER 5

DISCUSSION

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Chapter 5

DISCUSSION

5.1 Floral Resources Available for Butterflies

In the present study all the four sites representing good number of floral resources including, trees, herbs, shrubs, climbers and bamboos. A total of 44 families with 74, 70, 55 and 69 plant species, recorded at Site I, II, III and IV, respectively. Among them 16 fruit plant species were recorded at Site I and II, 13 at Site III and 15 at Site IV. Farooq and Arya (2018), also observed butterflies diversity in the temperate fruit tree orchids of Kumaun Himalaya.

The interaction between insects and flowers is essential because it produces a complex mutualistic pollination mechanism that is beneficial to both through synergistic and complementary effects (Corbet, 2000). It has been estimated that an average of 87% of the global flowering plant species rely on animals for pollination (Ollerton *et al.*, 2011). Moreover, about 80% of the wild floral biodiversity is directly dependent on butterflies for pollination (Ashman *et al.*, 2004; Potts *et al.*, 2010).

Butterfly diversity is higher in forest areas than in other types of ecosystems because forests provide a wider variety of microhabitats and resources that can support a rich variety of butterfly species (Joshi *et al.*, 2008). The availability of host plants for caterpillars is a significant factor. Different butterfly species have evolved to feed on various plant species, and forests typically contain a wide variety of plant species that can act as host plants. This means that a forest can support a wider variety of butterfly species than regions with fewer plant species. Previous studies also reported that the availability of habitat and food resources has been identified as one of the most important factors influencing butterfly habitat quality (Dennis and Sparks, 2006; Schlegel and Hofstetter, 2021). Due to monoculture systems, pesticide usage, habitat loss and fragmentation, agri-horticulture regions have less floral and butterfly diversity than forests. A greater variety of habitats are available in less disturbed forests, and natural ecosystems (New, 2005).

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The Natural forest of site I has a wide variety of flowers, which increases the diversity of butterflies. The findings coincide with several earlier studies which found that the diversity of butterflies is always greater at forest edges than agri-horticulture areas (Tiple and Khurad, 2009; Vu Lv, 2009). The diversity of butterflies increases with plant diversity, similar findings were also made by Murodch *et al.,* (1972); Stamps and Linit (1997); Becerra (2005); Proches and Cowling (2006); Wenninger and Inouye (2008). Despite the marginal difference in floral resources site II (semi-rural) represents, 28% of butterfly individuals. Site III represents least number of plant resouces, although that does not affect the diversity of butterflies. The site IV has a lesser diversity of butterflies due to it's semi-urban setting. It also has industrial area in vicinity thereby maximum human interference observe, which in turn influence the diversity and distribution of butterflies.

Sharma and Sharma (2013) studied the flower preferences of butterflies in Gir Wildlife Sanctuary and found that *Lantana camara* flowers were chosen more than others. Sajjad *et al.*, (2012) have reported the preference of flowers by different butterfly species during different seasons. Tiple *et al.* (2005) reported on 19 nectar plants from 12 different plant families, the majority of which were herbs with tubular flowers in the colors of red, yellow, blue, and purple that were more frequently visited than white and pink flowers. Butterflies visited a variety of flowering plants that produced nectar to collect nectar. A total of four butterfly species, *P. polytes, G. agamemnon, J. herita,* and *A. meriona*, have been supported by 86 plant species from 27 families in agricultural environments in the Chamarajanagar District by Santosh and Basavarajappa (2016).

5.2 Taxonomic Composition of Butterflies

Present study was conducted on butterflies in order to study their diversity and distribution in different sites of Haridwar, Uttarakhand. During the present study, several surveys have been conducted in between October 2019 to November 2021. These surveys resulted in enumeration of 90 species pertaining to 63 genera of 4 families.

Family Nymphalidae: Nymphalidae includes the brush footed butterflies, a total of 54 species were recorded during different seasons of the year 2019-2021. During the

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present study, 2945, 2709, 1920 and 1546 individuals were recorded from site I, site II, site III, and site IV respectively. Shields (1989) reported 6,440 species of Nymphalidae in the whole world. Whereas, from the Indian region, Varshney (1994) has shown 232 species, only 22 of it from Rajaji National Park (Arora, 1994). Mehta *et al.*, (2002), observed 14 species from Pong wetland Himachal Pradesh. Joshi and Arya (2007), have studied butterfly communities along altitudinal gradients in a protected forest in western Himalaya and found that Nymphalidae was the most abundant, both in terms of individuals and species.

Joshi *et al.*, (2008) have studied the effect of altitude, distribution as well as other ecological and climatic parameters on insect diversity and found family Nymphalidae most abundant with 10 species comprises of 890 individuals. Pandey *et al.*, (2013) also found Nymphalidae most dominant with 17 species in Askot Wildlife Sanctuary, Pithoragarh, Uttarakhand. 34 Species of Nymphalidae were recorded in Mayureshwar Wildlife Sanctuary, Baramati Tehsil by Khyade and Jagtap (2017).

Family Pieridae: Family Pieridae was represented by 20 species with 297, 265,171, and 112 individuals from site I, site II, site III, and site IV respectively.

Pieridae includes the white and yellow butterflies, it is considered one of the poorly understood family of butterflies, (Venables, 1993), consisting of more than 1000 species comprises in 98 taxa *i.e.* 83 genera and 15 subgenera (Braby, 2005). It is found second dominating family at Gurukula Kangri University, Campus, Haridwar, with representing 9 species out of 25 species (Kumar *et al.*, 2013). Arya and Dayakrishna (2014) observed species richness and diversity of sub temperate forest ecosystem of and around Kumaun University, Nainital, Uttrakhand. It was found dominating with 8 species, and contribute 41.91% of total individuals of butterflies. Study conducted at different altitudes of Uttarakhand, a total, 322 individual belongings to two different families were found, among them, Pieridae family found dominating, with 19 species. Maximum diversity of Pieridae was found at site of lowest altitude (300m), at Raja Ji National Park (Singh *et al.*, 2015). Lamiyan and Sharma (2018) studied the butterflies diversity of Roorkee, Haridwar, a total of 32 species belonging to five different families were found, among them Pieridae, was found second dominating after Nymphalidae with 7 species (Farooq and Arya, 2018).

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Family Papilionidae: Family Papilionidae was represented by 6 species with 98, 119, 66 and 42 individuals from site I, site II, site III and site IV respectively.

Family Papilionidae, includes the swallowtail and birdwing butterflies; this family is represented by 3 subfamilies, 289 genera and 566 species. Out of these 94 species spread over 10 genera are recorded from Indian region alone (Talbot, 1939). Other workers who had studied the distribution of Papilionidae are Mondal *et al.*, (1997), who recorded 5 species from Delhi, Rose and Sindhu (2001) reported 5 species belonged to family Papilionidae from Punjab state. Thakur *et al.*, (2006) recorded 2 species from Pin-Valley National Park (H.P.). Joshi *et al.*, (2008) found 3 species from Pindari forest of western Himalayas. Thakur and Mattu (2010) recorded 3 species from Shivalik hills of Himachal Pradesh. Khyade and Jagtap (2017), reported 13 species of butterflies belonging to the family Papilionidae, of which one is very rare, and three were found rare in distribution. 5 species, contributing 7.25% of total species diversity was recorded at Victoria Park Reserve Forest, Bhavnagar, Gujrat (Trivedi *et al.*, 2022).

Family Lycaenidae: Family Lycaenidae was represented by 10 species with 2043, 1906, 1340, and 1176 individuals from site I, site II, site III, and site IV respectively.

It includes the blue and copper butterflies. Rose and Sindhu (2001) had reported 24 species from Punjab, Mehta *et al.*, (2002) had studied species from Pong wetland Himachal Pradesh. Studies on diversity and distribution of 82 species of butterflies were also conducted by Arora *et al.*, (2005). Sharma and Joshi (2009) studied 41 species at Dholbaha dam in Hoshiarpur, Punjab. Sharma and Kumar (2013) made detailed observation in various agro-climatic zones of Renuka Lake in Sirmour. Similarly, Kumar *et al.*, (2016) had experienced 10 species from Chanshal Valley of Shimla. Lowest diversity *i.e.* 2 species, out of 33 species, were found in Lycaenidae family, in a study performed at three temperate fruit orchids of district.

5.3 Species Diversity, Species Richness and Evenness

During the study, the maximum diversity index (H) was found for Nymphalidae family (3.77) and minimum for Papilionidae family (1.49). The species richness varied from 0.86 to 5.83. The Pieridae family had the maximum evenness index (0.89) while the minimum for Lycaenidae family (0.55). The Simpson Diversity

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Index (D) varied from 0.73 to 0.97, whereas, Shannon equitability index varied in between 0.74 to 0.96.

During 2019-20, site I, showed maximum species diversity, richness and simpson diversity index for Nymphalidae, followed by Pieridae, whereas, Papilionidae and Lycaenidae have least values of Simpson diversity index. Similar trend observed during the period of 2020 to 2021. Similar pattern for these indices was also recorded from site II. Whereas, at site II Lycaenidae has the minimum value for species diversity, as compare to other families for the period of 2019-20. During 2020-2021, these indices were found same as recorded from site I and site II. At site IV Lycaenidae had minimum value for species diversity and Simpson diversity index, during the first year of study. During the second year of study, species diversity and Shannon equatibility indices were found in descending order of Nymphalidae, Pieridae, Paplionidae, and Lycaenidae.

According to earlier research (Kunte, 1997; Prajapati *et al.*, 2000; Shrestha *et al.*, 2020), Nymphalidae has the highest species richness, due to their polyphagous nature, this means different types of flowers and host plants will invite butterflies to nector or lay eggs on suitable plants. Nymphalidae was found from February to October at site I, March to October at site II. Good sighting were recorded from April to July from site III while lesser sighting were recorded in the month of February, March and August. Similar pattern was observed from site IV. We also recorded the feed sources for Nymphalidae are plants from families, Fabaceae, Asteraceae, and Poaceae. Peggie and Amir, (2006) recorded plants from family Fabaceae, Asteraceae, Poaceae and Annonaceae. While Saraf and Vijaykumar (2021), found that hot summers are not favourable for the activity of Nymphalidae in Kalaburagi, Karnataka.

5.4 Impact of Ecological Variables and Anthropogenic Activity on the Abundance of Butterfly

Butterflies are recognised as crucial indicator ecological dynamics. Butterflies have a great public appeal due to their well-known taxonomy and relatively large size and beautiful appearance. So, they are considered umbrella species in natural conservation and also act as key taxa in monitoring of biodiversity (New, 1995).

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They are also very sensitive towards environmental changes. Change in vegetation, land use and any swift transformation of environment can adversely affect the composition and abundance of butterfly species (Naik *et al.*, 2021).

Present study also deals with relation between different climate variables, such as temperature, relative humidity, along with selected soil characteristics, and afforestation to the distribution and abundance of butterflies.

Temperature:

Temperature was very influential parameter that effect the diversity of butterflies as ambient temperature of the environment regulates their body temperature (Horák *et al.*, 2021). Each butterfly species has different adaptability to temperature. Temperature have an important factor that effective role in metabolism, metamorphosis, mobility, host availability etc. which may influences the probability of change in butterflies population and their dynamics (Shrestha, 2019). Most butterfly species prefer open areas where the temperature is relatively high especially during the early time of the day (Larson, 2005).

Temperature can affect the insect species in several complex ways. In the present study, the temperature was found maximum, in the range of 39.30±0.80 °C to 43.42± 1.17 °C during the month of May and June, considered as hot summer period at all sites. While, remaining months minimum 19.96 ±1.05 °C (January) and maximum was 38.52±1.24 °C (April) at all the sites during 2019-2020. In the year, 2020-2021, May and June have minimum, 40.44±1.82 °C and maximum 41.22±1.29 °C at all sites. In reaming months, the temperature ranged between 23.28±1.18 °C (January) to 37.72±1.60 °C (July). Dumbrell and Hill (2005) also indicated that butterflies prefer areas where the temperature ranges between 28 °C-33 °C with optimum humidity. Butterflies can survive at the temperature range of 16 °C and 42 °C (Scoot, 1986), while the optimum temperature for butterflies is around 28 °C-35 °C (Watanabe and Imoto, 2003). Pearson correlation coefficient (r) between temperature and butterfly abundance was found positive correlated for all the four sites. Gupta *et al.*, (2019), also found species abundance and richness of butterflies, significantly positive correlated with temperature.

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Relative Humidity: Humidity is a very important climate factor. Humidity can also affect the breeding, growth, development, and activeness of butterflies. In the year 2019-20, the relative humidity (%) was recorded maximum in the range of 76.65±1.51% to 79.38±0.74% during the month of August and September, whereas, minimum was recorded in the month of May, i.e. 16.69±0.63% to17.65±1.17% at all sites. Similarly in the year 2020-21, the maximum humidity (%) ranged between 68.18± 1.12% to 79.13±0.22% in the month of August-September. Relative humidity was found good to moderate for the rest of the year, at all sites, for the period of 2019-2021. This might be due to sub-tropical climatic profile of Haridwar. The ability of the survival of butterfly species in the humidity of the surrounding atmosphere is different for each species and each developmental stage. The humidity may also affect the expansion of host plants and directly or indirectly affect the butterflies' diversity (Efendi, 2009). Similarly, during the present study, a good number of floral resources reflects the impact of humidity and thereby the diversity of butterflies in this area.

Rainfall: During 2019-2020, maximum rainfall was recorded 557.82±1.07 mm in the month of August. Good rainfall was received in the month of July and September while, moderate rainfall received in the month of January (148.63±0.96). The minimum was recorded in the month of November at all sites. Whereas, in 2020-2021, maximum rainfall reported in the month of August, good amount of rainfall received in July, moderate in the month of September, and least was received, 0.63±0.11mm in the month of October. Kunte (2001) and Pandhye *et al.* (2006) also stated that temperature is among one of the factors that directly affect the diversity of butterflies, richness and their population.

Naik *et al.*, (2021) also found that rainfall leads to lush vegetation, especially herbaceous and grass species, which can provide overabundance of habitat and food resources for many butterflies' species. Similarly, some species like *Taractrocera ceramas* depend on specific host plants, *i.e. Oryza sativa* which cultivated or emerge during monsoon period. However, Kunte, (1997) observed that some species population decrease in number during heavy rainfall to abvoid the harsh conditions. Bhaumik and Kunte, (2020), also observed migration in *Euploea spp. and Tirumala spp.*, towards plains to avoid southwest monsoon.

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Soil type: The sandy loamy soil type was observed in all the sites. In the year, 2019-2020, the values of pH was ranged between 7.34 to 8.18, organic carbon ranged between 1.18 to 4.72%, moisture content varied from 7.48 to 19.6%. Bulk density of soil ranged between 1.17 to 1.48 gm/cc. Whereas, in 2021, pH of soil was ranged between 7.48 to 8.23, organic matter was ranged between 1.23 to 4.89%, soil moisture varied from 7.84 to 22.68%, bulk density was found in the range of 1.18 to 1.64 gm/cc.

The presence of good amount of organic matter, reflects through the good moisture content at all sites, which might influence the floral resources and in turn, the diversity of butterflies. Inspite of good moisture and moderate temperature, Oak-FYM based rainfed agrosystem reported only one species of family Noctuidae (Pant, 2009).

Anthropogenic activity: Anthropogenic activity is a main reason for loss of biodiversity mainly through the modification of natural habitat (Walker, 2012). Continuous change in habitat and ecosystem is natural occurring process, however its pace can be increased because of anthropogenic activities (Lindenmayer and Likens, 2018). On Earth, habitat loss and fragmentation are two main threats that contribute to the decline in biodiversity (Harrison *et al.*, 2014; Foley *et al.*, 2005). Butterflies are a well-known group of insects. They have spread throughout the planet and extremely sensitive to changes in their habitat and climate (Warren and Bourn, 2011). They require a high abundance of host plants for the stages of development and egg laying, as well as a good quality environment to complete their life cycle. Biodiversity around the world is threatened by forest degradation due to fragmentation and human intervention (Houlihan *et al.*, 2013).

Urban sprawl has a negative impact on ecosystem functioning and biodiversity due to widespread human interference including agricultural land expansion and the destruction of natural habitats like grasslands and forests (Grimm *et al.*, 2008; Shochat *et al.*, 2010). Due to the growth of urban areas, residential colonies, highways, flyovers, and bridges etc., habitats for insects in general, and butterflies in particular have shrunk enormously in recent past. These factors have increased the techno-ecosystem, decreased natural habitats for other species to survive, and increased pollution in the environment (Mc Kinney 2002; Pocewicz *et al.*, 2009).

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Rathcke and Jules (1993) had studied that rapid expansion of urban areas are responsible for, habitat loss, habitat alteration and increase different type of pollutions, such as, air, water, soil, noise pollution, theses pollution along with anthropogenic factors cause unpleasant impact on floral and faunal communities.

The diversity and abundance of butterfly species is greatly associated with the availability of food plants in the surrounding habitat (Kunte *et al.*, 1999). The diversity of butterflies depends upon overall floral diversity especially in forest and grassland (Padhye *et al.,* 2006). The elimination of grasses, shrubs and trees during landscaping has resulted in loss of food substrate plants for butterflies, leading to change in species composition (Balmer and Erhardt, 2000). Similar, observations were recorded for the site IV, which has industrial area in vicinity. Butterflies are sensitive to habitat fragmentation as they are host specific (Thomas *et al.*, 2001; Eichel and Fartmen, 2008; Garcia-Barros and Fartmann, 2009). Addai and Baidoo (2013) observed that undisturbed canopy of Bosomkese Forest Reserve had highest number of greatest diversity and highest no. of species richness, whereas the disturbed canopy, having anthropogenic activity had least butterfly diversity and richness.

From the present study, the highest butterfly diversity was recorded at the site I, while the lowest diversity of butterfly was recorded at the site IV. Site II and III had relatively lesser values for species diversity, due to the changes in land use as, vast fringe forest converted into the agriculture land, and that leads to loss of natural vegetation. Negi (1995) also found that most part of lowland forest in Uttrakhand, have been cleared for agriculture. The diversity of wild plants supports a wide range of pollinators, including butterflies, and provides microhabitat for egg laying and larval development. A monoculture crop produces less favourable environments for insect egg-laying and larval development phases (New, 2005).

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SUMMARY

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SUMMARY

Butterfly biodiversity is a component of our natural heritage and has been researched for more than 300 years. A taxonomically well-studied group of insects, butterflies are known for their diurnal activity patterns and easily recognised traits. Butterflies have complex relationships with a variety of biotic and abiotic elements. They are widely distributed around the world and can be found in a range of habitats, including grasslands, scrublands, gardens, fields, deserts, and woods, in places like the tropics, circumpolar snowy regions, coasts, and the highest mountains Butterflies have colourful wings that vary in size, brilliance, and pattern, making them some of the most endearing and fragile creatures. Himalayan butterflies fall into two major ecological groups *i.e.* forest species and the hysobiont species. The forest species are confined to more or less densely wooded mountain slopes of the outer Himalayan range. The hysobiont species are true high-altitude forms that never occur below the timberline.

The state of Uttarakhand is distinctive for its abundant biodiversity, with a total area of 53,483 sq. km, of which 65% area under forest. Keeping in view, the physiographic profile of Haridwar, the present investigation designed to assess "Distribution pattern of butterflies (Lepidoptera: Rhopalocera) in different habitats of District Haridwar, Uttarakhand" with the following objectives:

I. Determination of floral Resources available for butterflies in different study site;

II. Species composition and population dynamics of butterflies in different study sites;

III. Comparison of species diversity of butterflies of different study sites and

IV. Role of Ecological variables viz. temperature, Humidity, Soil type and anthropogenic disturbances on the abundance of butterflies.

Floral Resources Available for Butterflies:

Site I: A total of 74 species of plants were recorded during the study period which included 36 trees, 14 shrubs, 21 herbs, 02 climbers, and 01 of bamboo. This site in terms of trees was mainly dominated by *Mangifera indica, Cedrela toona*, *Syzygium cumini*, *Ficus religiosa*, *Phyllanthus embilica*, *Senegalia catechu* and *Dalbergia sisso*.

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The dominant shrubs species were included *Murraya koenigii, Zizipus jujupa, Solanum torvum* and *Datura alba;* while in herbs, the dominant species were *Ageratum conyzoides, Cannabis sativa, Parthenium hysterophorus,* and *Oplimensus burmannii.* The area was sparsely occupied by the climbers and bamboo species.

Site II: A total of 70 species of plants were recorded during the study period *i.e.* 2019-21 which included 35 trees; 16 shrubs; 18 herbs and 01 climber. The commonly observed trees were *Cedrela toona; Syzygium cumini; Phyllanthus embilica; Citrus aurantifolia; Citrus limon; Corymbia citridora* and *Mangifera indica.* The recorded shrubs species included *Murraya koenigii*; *Zizipus jujupa*; *Desmodium ganeticum*; *Hibiscus rosasinensis* and *Rosa indica*; herbs species included *Cannabis sativa, Parthenium hysterophorus, Solanum xanthocarpum, Solanum nigrum.* The area was sparsely occupied by the climber.

Site III: A total of 55 species of plants were recorded during the study period *i.e.* 2019-21 which included 23 trees, 13 shrubs; 17 herbs and 02 climbers. The commonly observed trees were *Emblica officinalis*, *Cedrela toona*, *Punica granatum*, *Magnifera indica* and *Corymbia citridora*; observed shrubs were *Rosa moschata*, *Nerium indicum*, *Lantana indica,* and *Murraya koenigii*; commonly recorded herbs were *Ichnocarpus frutescens*, *Euphorbia hirta, Solanum nigrum* and *Cannabis sativa.* The area was sparsely occupied by the climber.

Site IV: A total of 69 species of plants were recorded during the study period *i.e.* 2019-21, which included 33 trees; 16 shrubs; 18 f herbs; 01 climbers, and 01 bamboo, respectively. Commonly found trees were *Mangifera indica, Corymbia citridora, Cedrela toona, Punica granatum, Phyllanthus embilica, Citrus limon* and *Dalbergia sisso*; observed shrubs were *Desmodium ganeticum*, *Murraya koenighii*, *Datura alba*, *Rosa indica* and *Sida rhombifolia*; commonly distributed herbs were *Ageratum conyzoides*, *Cannabis sativa*, *Solanum nigrum* and *Cyprus rotundus.* The area was sparsely occupied by single climber and bamboo species.

Taxonomic Composition of Butterflies

During the present study a total number of 16,330 individuals of order (Lepidoptera) belonging to 90 species and 04 families were reported. Out of total individuals

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observed during study maximum number belongs to family Nymphalidae (Brush footed butterflies) (54) followed by Pieridae (White and yellow) (20), Lycaenidae (Blues) (10) and Papilionidae (Swallowtails) (06). During the first year of study (2019-2020) Nymphalidae, contributed 53.48%, Pieridae (40.48%), Lycaenidae (4.01%), and Papilionidae (2.03%) to the total population of butterflies. The similar trend was observed during 2021-2021, where family Nymphalidae contributed with 55.88%, Pieridae (36.67%), Lycaenidae (5.52%) and Papilionidae (1.92%).

Nymphalidae was the most dominant family with 54 species and total number of 8945 individuals and constitute 54.78% of total butterflies recorded during 2019-2021. *Danaus chrysippus* (Linn.) was the most abundant, followed by *Telinga malsarida* (Moore), *Ariadne merione* (Cramer), *Phalanta phalantha* (Drury), *Danaus genutia*, *Vanessa indica* (Herbst), *Ypthima indecora* (Moore), *Pseudergolis wedah* (Kollar), *Aglais caschmiremsis* (Kollar), *Melanitis leda* (Linn) *Junonia lemonias* (Linn.), *Vanessa carduii* (Linn), *Neptis sankara* (Kollar), *Junonia almana* (Linn.), *Rohana parisatis* (Westwood), *Junonia orithya.*

Pieridae was recorded a total of 6275 individuals, of 20 species, and contributed 38.43% towards the total of Lepidopterans during study. *Eurema hecabe* (linn.) was the most abundant species of this family followed by *Pieris canidia* (Sparrman.), *Pieris brassicae*, *Eurema laeta* (Bio.), *Catopsilia pomana* (Fab.), *Delias eucharis* (Drury), *Gonepteryx rhamni* (Linn.), *Eurema brigetta* (Cramer), *Colias fieldii* (Meneteris), *Appias albina* (Bio.), *Catopsilia florella* (Fab.), *Ixias pyrene*, *Leptosia nina* (Fab.), *Pareronia hippia* (Fab.), *Cephora nerissa.*

Papilionidae was represented by 322 individuals of 06 species. *Papilio demolius* (Linn.) was the most abundant species and contributed to this family followed by *Graphium doson* (Felder), *Papilio protenor* (Cramer), *Papilio polytes* (Linn.), *Graphium cloanthus* (Westwood), *G. serpedon.*

Lycaenidae was recorded a total of 788 individuals of 10 species and contributed 4.82% to the total Lepidopterans record during present study. *Zizina labradus* was the dominant species followed by *Dodona durga*, *Pseudozizeeria mah*, *Jamides alecto* (Felder), *Virachola isocrates* (Fab), *Acytolepis puspa* (Horsfield), *Tajuria cippus*

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(Fabricius), *Lampides boeticus* (Linn.), *Castalius rosimon* (Fab.), and *Talicada nyseus* (Guerin).

Species Diversity, Species Richness and Evenness

Site I: In the year 2019-20, Species diversity (H) was recorded 3.80, 2.92, 1.56, and 1.73 for Nymphalidae, Pieridae, Papilionidae and Lycaenidae respectively. The Shannon equitability index 0.96, 0.97, 0.97 and 0.88 were recorded for family Nymphalidae, Pieridae, Papilionidae and Lycaenidae respectively. Simpson Diversity Index, 0.97, 0.94, 0.77 and 0.78 were recorded for Nymphalidae, Pieridae, Papilionidae and Lycaenidae respectively. Whereas, in the year, 2020-21, species diversity (H), Shannon equitability and Simpson diversity indices shows similar trend with slight change in the values.

Site II: In the year 2019-20, species diversity (H) was recorded 3.65, 2.85, 1.24, and 1.41 were recorded for Nymphalidae, Pieridae, Papilionidae and Lycaenidae respectively. The Shannon's equitability index, was recorded 0.95, 0.95, 0.77 and 0.78 for Nymphalidae, Pieridae, Papilionidae and Lycaenidae respectively. The values of Simpson Diversity Index, were 0.97, 0.93, 0.62, and 0.68 for Nymphalidae, Pieridae, Papilionidae and Lycaenidae respectively. This site showed similar trend in the year 2020-21, for the considered indices.

Site III: In the year, 2019-20, the species diversity (H) was recorded 3.62, 2.82, and 1.35 for Nymphalidae, Pieridae, Papilionidae and Lycaenidae respectively. The Shannon equitability index recorded 0.94, 0.97, 0.99 and, 0.75 for Nymphalidae, Pieridae, Papilionidae and Lycaenidae respectively. Simpson Diversity Index, reported 0.96 0.93 0.74, and 0.33 for Nymphalidae, Pieridae, Papilionidae and Lycaenidae respectively. At this site, Lycaenidae recorded minimum values for all three indices, as compared to site I and II, where, minimum was found for family Papilionidae. In the year 2020-21, these indices exhibits same pattern as observed in case of site I and site II.

Site IV: In the year, 2019-20, the species diversity (H) recorded were 3.49, 2.75, 1.12, and 1.04, for Nymphalidae, Pieridae, Papilionidae and Lycaenidae respectively. Shannon equitability index evenness values were recorded 0.95, 0.97, 1.02 and 0.75

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for Nymphalidae, Pieridae, Papilionidae and Lycaenidae respectively. Simpson Diversity Index was found 0.96, 0.93, 0.68, and 0.56 for Nymphalidae, Pieridae, Papilionidae and Lycaenidae respectively. In the year 2020-21, similar trend as of 2019-20, was recorded.

Impact of Ecological Variables and Anthropogenic Activity on the Abundance of Butterfly

The maximum temperature was recorded during the month of May and June, in the range of 43.4 to 39.3 °C at all sites for the period of 2019-21, whereas, minimum diurnal temperature was recorded in the month of January in the range of 19.96 °C to 24.39 °C. In the year 2019-20, maximum temperature were recorded, 42.93°C, 43.35°C, 43.42°C and, 42.89°C for site I, II, III, and IV, in the month of June while the minimum temperature were 19.96°C, 21.29 °C, 21.55°C and 21.66°C for site I,II,III, and IV, in the month of January. Similar pattern was observed during the year 2020-21. A positive correlation was observed between temperature and butterfly abundance.

In the year 2019-20, the maximum humidity (%) were recorded 78.26, 78.83, 79.11 and 79.38 for site I, II, III, and IV, in the month of September. However the minimum humidity were recorded 16.69, 17.02, 17.39 and 17.65 for site I, II, III, and IV in the month of May. Similar trend of humidity was observed in the year of 2020-21.

In the year 2019-20, the maximum rainfall (mm) were recorded 556.28, 557.29, 556.70 and 557.82 for site I, II, III, and IV, in the month of August, while minimum rainfall was recorded 6.83, 7.74,6.85 and 7.55 for site I, II, III and IV respectively in the month of November. In the year 2020-21, maximum precipitation received in the month of August. Good to moderate rainfall in the month of July and September and least (0.63) to no precipitation was observed in the month of October.

All the sites have sandy loam texture. In the year 2019-20, the bulk density (gm/cc) recorded 1.48, 1.21, 1.26 and 1.17 for site I, II, III, and IV respectively. Moisture content (%), 19.60, 11.89, 8.67 and 7.48 were recorded at site I, II, III, and IV. Chemical parameters such as pH and organic carbon (%) were found in order of 8.18,

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7.84, 7.69, and 7.34 and 4.72, 2.86, 1.45, and 1.18 % respectively at site I, II, III, and IV. In the year 20202-21, bulk density, were recorded 1.64, 1.34, 1.18, and 1.23 at site I, II, III, and IV respectively. Whereas, moisture content, pH and organic carbon showed similar trend as previous year.

Human intervention and other developmental activities, influences the distribution and diversity of butterflies in and around Haridwar. We observed, maximum butterfly diversity at site I, due to presence of natural forest while the minimum was recorded at the site IV, as this area has myriads of industries. Site II and III had relatively lesser values for species diversity, due to the changes in land use as, vast fringe forest converted into the agriculture land, and that leads to loss of natural vegetation.

Significance of proposed work

This study would be helpful in providing the baseline data of the role of climatic variables in diversity and distribution of butterflies and also a step in providing sustainable ecosystem habitats.

Recommendations

Based on present study, the following recommendations are made for future work.

- Work on physiological attributes of various insects including Lepidopterans, collected from fields should be undertaken to study the behavior of the insects.
- Lepidopterans host plants of rare and endangered species, should be planted and conserved to improve the Lepidopteran species.
- Molecular level studies, *viz.*, chromosomal variations should be considered in future studies.
- Develop and maintain certain zone of wilderness for conservation of butterflies even in urban centre.
- The areas needs to be monitor on regular bases and efforts to be made to know it's floral and faunal components and there is need to have vision document for sustainable development and conservation of it's rich biodiversity.
- Many more species could be added to the list for further exploration of rural areas of Haridwar.

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Diversity Pattern of Butterfly Communities in Different Habitat Types of District Haridwar, Uttarakhand, India

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ABSTRACT During the years 2019–2020, the diversity of butterfly communities in Haridwar, Uttarakhand, India, was investigated in four different habitat types (natural forest [Kangri], agri-horticulture [Jagjeetpur], agriculture [Laksar], and barren industrial region [Bahadrabad]). A total of 84 species were identified, with 7533 individuals belonging to four different groups. During the study period, the Nymphalidae family was found to be the most prevalent group while family Papilionoideae with least species diversity. From the natural forest to the industrial site, the number of rare species decreases, while the proportion of common species rises from the agro-horticulture region to the natural forest site. The streamside environment in the forest is critical for butterfly conservation, whereas barren ground has the least butterfly diversity. Butterflies are progressively being perceived as important natural markers, both for their fast and delicate reactions to inconspicuous environment or climatic changes and as delegates for the variety and reactions of other untamed life.

KEY WORDS Association, Butterfly, Habitat, Species composition

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INTRODUCTION

Butterflies are classified like insects and belong to the Lepidoptera order, which is the second biggest of all animal orders. "Scale wings" is what the name Lepidoptera means (Greek; Lepis-scale; Pteron-wing). They are among the most beautiful and interesting animals on the planet, and they perform an important role in both the environment and human health. They are generally allowed to as "bugs of the sun" with their eye getting shading and sensitive allure (Haroon, 2016). Butterflies are among the most essential insects in ecosystems, and their abundance and variety are practical markers of the health of any particular terrestrial biotope (Clarke and Dennis, 2020). Butterflies (Lepidoptera: Rhopalocera) are one of the most plant subordinate gatherings among insects when contrasted with the other megadiverse bug gatherings (Kristensen and Skalski, 1990). Butterflies are gainful as they fill in as pollinators and signs of ecological quality and are valued for their tasteful worth (Ismail, 2020). Climatic changes impact the variety of species and are expected to worsen the biological systems (Dobrowski, 2021). The progressions in boundaries of temperature, precipitation examples, and extreme weather patterns, for example, heatwaves, delayed dry season, or unreasonable precipitation, have to be taken into consideration. The life history of holometabolous butterflies reveals that Lepidoptera is exposed to a wide range of ecological effects and is extremely sensitive to temperature, light levels, and mugginess (Hill, 2021). India addresses one of the "megadiverse" nations of the world. Out of around 25,000 types of butterflies recorded from all over the world, 1501 are from India (Gay, 1992).

Uttarakhand has a scope of assorted flower and faunal wealth. Geographically, it shares the piece of both Central and Western Himalayan regions and is situated in the central area of the Himalayas, subsequently inferable from its distinctive and rich biodiversity. A few examinations on butterfly variety have been directed in this state which is either restricted to just safeguard regions (Shivani and Narender, 2019; Joshi, 2007; Cerrato *et al.*, 2019; Shouche

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and Ratnakar, 2018; Kumar *et al.*, 2017; Farooq *et al.*, 2018; Verma *et al.*, 2018; Arya *et al.*, 2020; Verma and Arya, 2018; Gadagkar *et al.*, 1990).

MATERIALS AND METHODS

The results presented here are based entirely on a 365-day monthly sampling of butterflies from April 2019 to March 2020. Haridwar district is located in Uttarakhand, India, and covers an area of around 2360 square kilometers. It is located at 29.58° N and 78.13° E latitude and longitude, respectively, with an elevation of 249.7 m above sea level. As per the conventional technique, the insects were captured using the "Sweep Sampling Method" (Gadagkar *et al.*, 1990). Because butterflies are usually active in the early hours of the day, the collection was done in the early hours of the day. As a result, it was simple to observe and gather them. Butterflies were either identified immediately within the area or, in rare situations, specimens were identified with the help of scientists from other associations.

Sampling and Identification of Butterflies

The butterfly survey was conducted at four locations in the Haridwar district: Kangri (Site 1), Jagjeetpur (Site 2), Laksar (Site 3), and Bahadrabad (Site 4). (Habitats: Agricultural atmosphere, barren land, horticulture ecosystem, and degraded forest). A monthly visit to Site 1, Site 2, Site 3, and Site 4 during optimal climatic conditions was used to conduct the observation (no heavy rain and sturdy wind). The series of specimens were executed with the help of insect nets following a sweeping sampling method (Shivani and Narender, 2019). Most of the butterflies were photographed and identified. When it became difficult to evaluate, then specimens were captured for further identification and after identification, they have been released in their herbal habitat straight away. Butterflies were seen, taken, recognized, and released right where they were caught. Collecting live specimens was avoided during the study. General identification of butterflies was done through the book "The Butterflies of India" and the website *https://www.ifoundbutterflies.org/*. For the appropriate identification of butterflies, scientists from the Indian Agriculture Research Institute, New Delhi, the Zoological Survey of India, Kolkata, and the Forest Research Institute, Dehradun, were consulted.

Statistical Analysis

The species composition between sites was measured following the standard methods. The data thus obtained were statistically analyzed using SPSS, Excel, and PAST software.

RESULTS

During the study period of 2019–2020, 84 distinct species of butterflies, including 7533 individuals, were recorded from four different habitat types. Table 1 shows the butterfly species and their abundance. *Eurema hecabe* (270 individuals) and *Eurema laeta* (270 individuals) are the two most common species (217 individuals). With 75 and 70 individuals, respectively, the Jagjeetpur and Kangri areas had the most *E. hecabe* individuals, while the dense forest of Kangri and the agri-horticulture region had the most *E. laeta* people, with 72 and 60 individuals, respectively. Table 2 shows the butterfly community diversity in four different habitat types calculated from the study region. Kangri has the most species (84), while Bahadrabad has the fewest (63 species) (Arya *et al.*, 2020). Kangri has the highest number of individuals (2461), while Bahadrabad has the lowest number (1308 individuals) (Fig. 1). The Kangri study site has the highest species richness index, whereas Bahadrabad has the lowest. The Kangri site has the highest evenness index, while the Jagjeetpur location has the lowest. Despite having the most individuals and species, the Kangri area has the highest evenness index and the highest diversity index. The butterfly community in Bahadrabad has the lowest diversity index. Figs. 2 and 3 show how butterfly communities from different habitats in the study area are comparable. Butterfly communities in four different settings are grouped into two categories based on their similarities. The dense woodland and agri-horticulture area is one group, while the agricultural and barren-industrial area is the other. According to the Bray-Curtis similarity index, Kangri and Jagjeetpur have similar species compositions. It also shows that Kangri has the highest species composition, followed by Jagjeetpur, Laksar, and Bahadrabad. Fig. 4 shows the distribution of butterfly species observed on major and minor axes using principal component analysis based

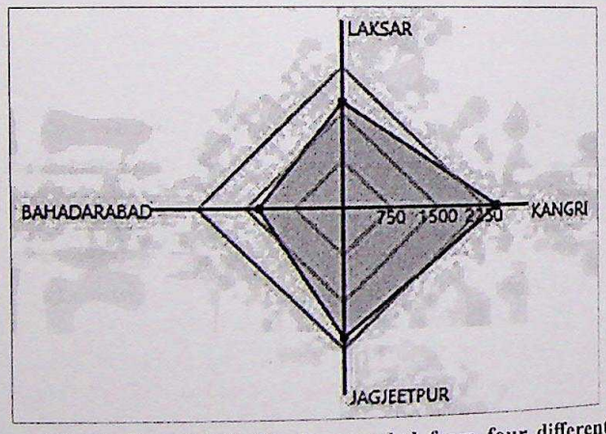

Fig. 1. No. of individuals recorded from four different habitat types.

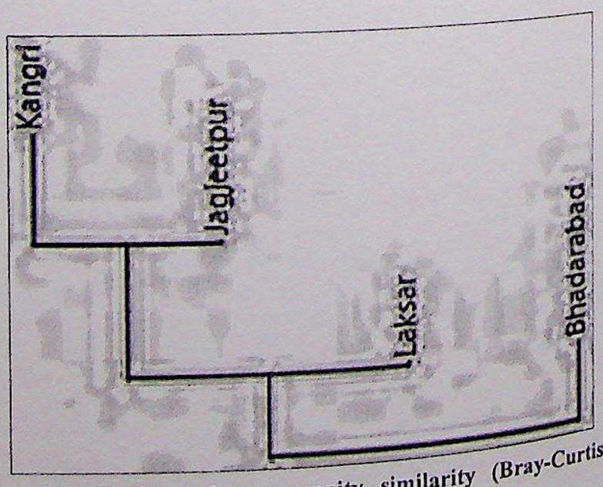

Fig. 2. Butterfly community similarity (Bray-Curtis similarity index) in different habitats.

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Table 1. Species list and relative abundance (%) of butterflies in different habitats

Species	S1 (Kangri)	S2 (Laksar)	S3 (Bahadrabad)	S4 (Jagjeetpur)	Relative abundance (%)
Family: Nymphalidae					
Junonia orithya	+	+	+	+	0.6
Melanitis leda	+	+	+	+	1.79
Parentica sita	+	+	+	-	0.33
Junonia almana	+	+	+	+	1.51
Aglais cashimirensis	+	+	+	+	1.89
Danaus chrysippus	+	+	+	+	2.72
Phalanta phalantha	+	+	+	+	2.12
Eupolea klugii	+	+	+	+	1.26
Athyma perius	+	+	+	+	1.06
Athyma selenophora	+	+	–	+	0.99
Junonia lemonias	+	+	+	+	1.72
Ariadne merione	+	+	+	+	2.25
Kallima inachus	+	–	–	+	0.21
Hestinalis nama	+	+	–	+	0.73
Pseudergolis wedah	+	+	+	+	1.92
Neptis sankara	+	+	–	+	1.63
Elymnias hypermnestra	+	+	–	+	1.31
Vanessa indica	+	+	+	+	1.99
Danaus genutia	+	+	+	+	2.05
Vanessa cardui	+	+	+	+	1.63
Neptis yerburgi	+	+	–	+	0.7
Phalanta alcippe	+	+	–	+	0.55
Neptis mahendra	+	+	+	+	0.73
Hypolimnas bolina	+	+	+	+	0.79
Junonia atlitis	+	+	+	+	0.94
Mycaleis perseus	+	+	+	+	0.66
Ypthima baldus	+	+	+	+	0.51
Eupolea core	+	+	+	+	0.74
Vindula erota	+	+	+	+	0.84
Eupolea mulciber	+	+	+	+	0.5
Acraea issoria	+	–	–	+	0.17
Charaxes bernardus	+	–	+	–	0.06
Neptis hylas	+	+	+	–	0.3
Euthalia aconthea	+	+	–	+	0.43
Libythea myrrha	+	–	–	+	0.13
Hypolimnas missipus	+	+	–	+	0.53
Ypthima newara	+	+	+	+	1.63
Neptis narayana	+	+	+	+	1.24
Cyrestis thyodamas	+	+	–	–	0.26
Rohana parisatis	+	+	+	+	1.47
Neptis nata	+	+	+	+	0.84
Junonia hierta	+	+	+	+	0.45
Junonia iphita	+	+	+	+	1.1
Acraea terpsicore	+	–	+	+	0.27
Parentica aglea	+	+	+	+	1.15
Danaus plexippus	+	+	+	+	0.55
Tirumala limniace	+	+	+	+	0.74

(*Contd...*)

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Table 1. (*Continued*)

Species	S1 (Kangri)	S2 (Laksar)	S3 (Bahadrabad)	S4 (Jagjeetpur)	Relative abundance (%)
Ypthima indecora	+	+	+	+	1.92
Danaus melanippus	+	−	−	+	0.09
Telinga malsarida	+	+	+	+	2.42
Ypthima avanta	+	+	+	−	0.39
Ypthima nareda	+	+	+	+	0.38
Family: Papilionoideae					
Papilio demoleus	+	+	+	+	0.86
Graphium cloanthus	+	−	−	+	0.13
Papilio protenor	+	+	+	+	0.34
Papilio polytes	+	+	−	+	0.22
Graphium doson	+	+	+	+	0.46
Family: Pieridae					
Catopsilia pomona	+	+	+	+	2.58
Pareronia hippie	+	+	+	+	1.65
Appias albina	+	+	+	+	2.32
Cephora nerissa	+	−	+	+	1.59
Belenois aurota aurota	+	+	−	+	2.05
Eurema hecabe	+	+	+	+	3.58
Colias fieldii	+	+	+	+	2.42
Pieris brassicae	+	+	+	+	2.96
Pieris canidia	+	+	+	+	3.01
Aporia agathon	+	+	+	+	0.73
Colotis danae	+	+	−	+	0.29
Hebomoia glaucippe	+	−	−	+	0.19
Leptosia nina	+	+	+	+	1.75
Ixias pyrene	+	+	+	+	2.08
Eurema laeta	+	+	+	+	2.88
Delias eucharis	+	+	+	+	2.4
Catopsilia florella	+	+	+	+	2.15
Pareronia valeria	+	+	+	+	0.99
Eurema brigetta	+	+	+	+	2.32
Gonepteryx rhamni	+	+	+	+	2.45
Family: Lycaenidae					
Zizina labradus	+	+	+	+	1.91
Virachola isocrates	+	+	−	+	0.19
Acytolepis puspa	+	−	−	+	0.13
Jamides alecto	+	+	+	+	0.45
Tajuria cippus	+	+	−	−	0.05
Pseudozizeeria mah	+	+	+	+	0.46
Dodona durga	+	+	+	+	0.79

on variance and covariance matrix. There are two separate groups: A densely packed species group on the left side of the first axis and a sparsely distributed species group on the right side of the first axis. The first and second primary components combined contribute 94.0% of the total. The findings indicate that the Kangri and Jagjeetpur have the highest species richness followed by Laksar and Bahadrabad.

DISCUSSION

The natural forest at Kangri has high floral diversity leading to higher butterfly richness. Bahadrabad being the industrial area with barren land represented the least number of individuals. The remaining study sites having mostly agricultural and horticulture type of habitats represented the

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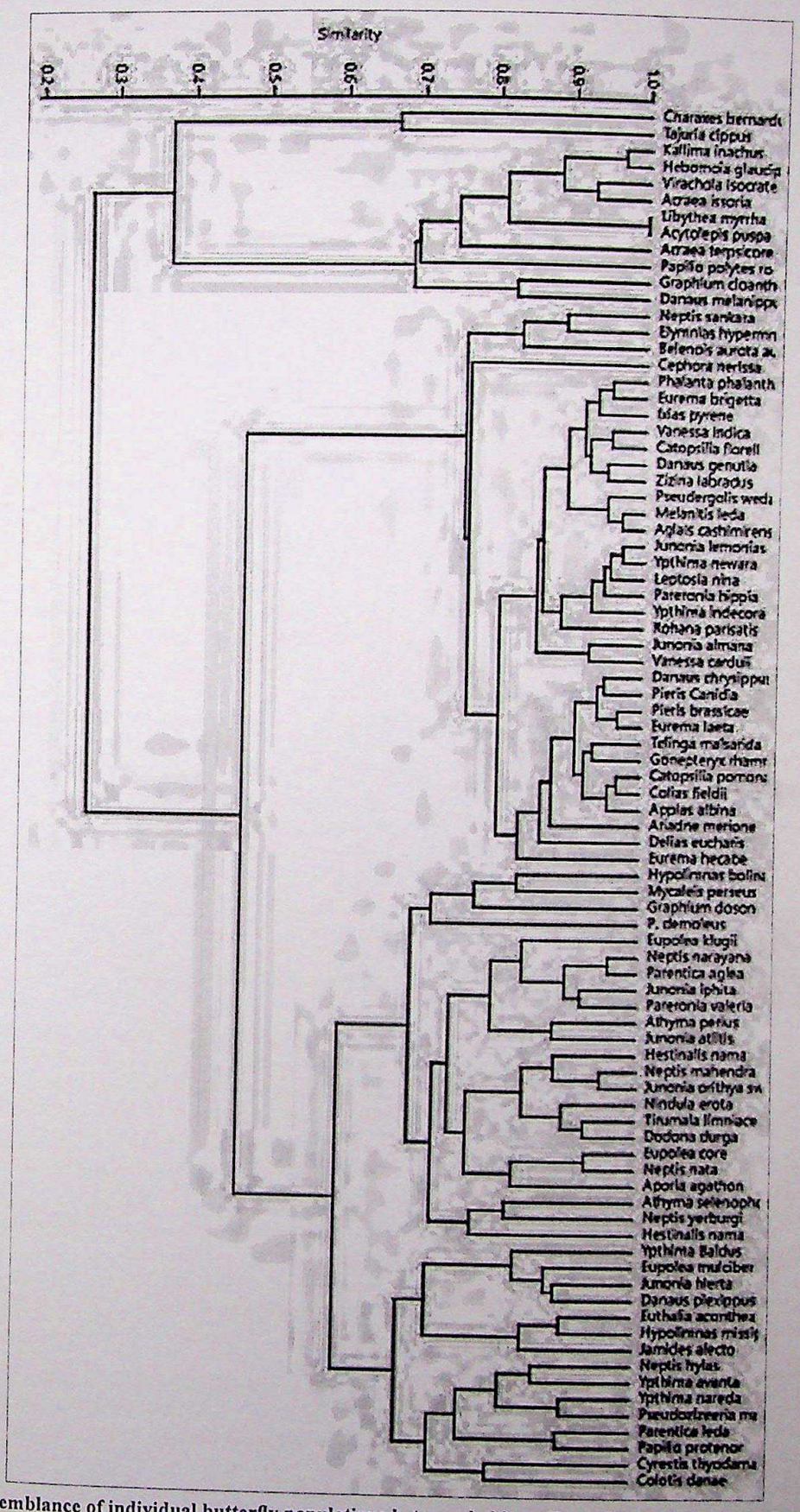

Fig. 3. The resemblance of individual butterfly populations between habitats (Bray-Curtis similarity index).

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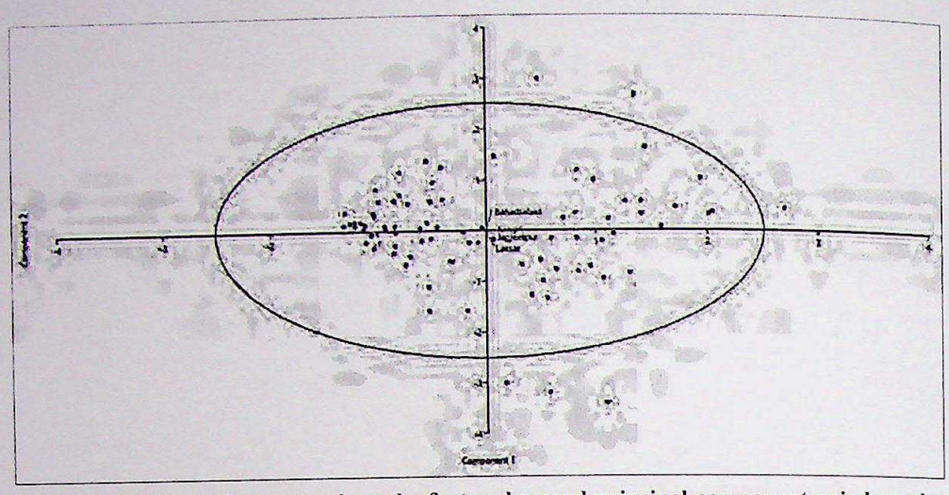

Fig. 4. Scattergram of 84 butterfly species along the first and second principal component axis by principal component analysis (PCA) ordination.

Table 2. Butterfly community diversity across four habitat categories

	Kangri	Laksar	Bahadrabad	Jagjeetpur
Taxa_S	84	74	63	78
Individuals	2461	1687	1308	2077
Dominance_D	0.01685	0.02007	0.0235	0.01907
Simpson_1-D	0.9832	0.9799	0.9765	0.9809
Shannon_H	4.219	4.05	3.905	4.093
Evenness_e^H/S	0.8094	0.7755	0.7878	0.7678
Brillouin	4.136	3.951	3.797	4.005
Menhinick	1.693	1.802	1.742	1.711
Margalef	10.63	9.824	8.64	10.08
Equitability_J	0.9523	0.9409	0.9424	0.9394
Fisher_alpha	16.83	15.82	13.81	16.01
Berger-Parker	0.02926	0.03853	0.04587	0.03611
Chao-1	84	74	63	78

intermediate but ideal diversity of the butterflies. The findings of this study corroborate previous research that suggests that butterfly diversity is always higher near forest edges than in agri-horticulture ecosystems (Basavarajappa and Gopi, 2018; Bergman *et al.*, 2018, Tiple and Khurad, 2009).The disturbed habitat's living environment is heterogeneous, with a variety of flora in the intermediate procession. Opening ideal blossoming plant types and shrubs is what this entails. Natural woods feature a greater variety of plants from various convoys than other ecosystems. Insect diversity increases as plant diversity increases (Becerra, 2015; Proches and Cowling, 2006; Wenninger and Inouye, 2008). Kangri is a natural forest but along the edges near the river Ganges, there are human settlements which lead to some disturbance in the particular area. The current findings are corroborated by previous research that found that when natural forests are damaged, the diversity of species, and individuals in butterfly groups rises, with the highest diversity found in moderately disturbed forests (Pureswaran *et al.*, 2018; Seidl *et al.*, 2011). The diversity of butterflies around the river was high during the research period. The living environment near the river's edge is diverse, with flora, rocks, sand, and water, attracting butterflies as they land and drink water and nutrients from the ecosystem. Wet sites are generally having greater insect diversity as compared with dry sites (Brenes-Arguedas *et al.*, 2009; Jenber and Wili, 2021; Liebhold *et al.*, 2018). Rare species are more abundant in natural forests, and this statistic reduces as habitat openness levels increase. Industrialization results in a decrease in the vegetation cover in that particular area. Lower butterfly diversity can be attributed to an increase in anthropogenic activity rates, a dearth of floral supplies, and high levels of pollution at the Bahadrabad location). Similarly, the presence of a sugar mill in the Laksar site also affects the butterfly diversity, but this factor is neutralized by the abundant diversity of floral resources in this study site. The results of the presented study are supported by the results of earlier workers (Parikh *et al.*, 2021; Jana *et al.*, 2012; Uhl *et al.*, 2020).

CONCLUSIONS

According to the findings, the number of rare species decreases as one moves from natural forest to industrial site, while the proportion of common species increases as one moves from agro-horticulture to natural forest. The streamside environment in the forest is critical for butterfly conservation, whereas barren ground has the least butterfly diversity.

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CONFLICTS OF INTEREST

The authors do not have any conflicts of interest.

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DEPARTMENT OF BOTANY
CHAMAN LAL MAHAVIDYALAYA
LANDHAURA, HARIDWAR (UTTARAKHAND)

1st NATIONAL CONFERENCE IN BOTANY

STATUS OF UPCOMING TRENDS IN BIODIVERSITY CONSERVATION

Certificate

THIS IS TO CERTIFY THAT

Prof./Dr./Mr./Ms. SHIVALIKA SHARMA FROM GURUKUL KANGRI UNIVERSITY, HARIDWAR

HAS PARTICIPATED AS (KEY SPEAKER/CHAIR PERSON/INVITED SPEAKER/AUTHOR/DELEGATE) IN THE NATIONAL CONFERENCE ON **STATUS OF UPCOMING TRENDS IN BIODIVERSITY CONSERVATION**

SPONSORED BY UTTARAKHAND STATE COUNCIL FOR SCIENCE & TECHNOLOGY (DEHRADUN)

ORGANIZED BY DEPARTMENT OF BOTANY, CHAMAN LAL MAHAVIDYALAYA, HARIDWAR.

HE/SHE PRESENTED A ORAL PRESENTATION/POSTER ENTITLED ROLE OF BUTTERFLY IN POLLINATION

(Dr. Sushil Upadhyay)
PRINCIPAL

(Dr. Richa Chauhan)
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